
Electrical
Experiments
By
G E Bonney

ELECTRICAL EXPERIMENTS.

BONNEY.

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A Manual of Instructive Amusement.

BY

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WITH 144 ILLUSTRATIONS.

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PREFACE.

This book is written in response to suggestions received from correspondents, and hints given in letters sent to the Editor of *Work*, that I should write a book showing how Induction Coils and other electrical apparatus can be used for instructive amusement. My correspondents state that a large number of idle hours hang wearily on the hands of youths during the long winter evenings in country villages, which could be spent in profitable amusement if they only knew how to use easily-made electrical apparatus. In the following pages I have shown how to derive amusement from instruments made at home from materials obtained at little cost, commencing with the homely sixpenny horseshoe magnet, the toy of every schoolboy.

As a description in detail of every instrument would have occupied too much space in this book, and has been fully given in other volumes issued by the publishers, I have referred readers to those books, wherein

they will find full illustrated instructions for making Induction Coils, Batteries, Dynamos, and other electrical instruments. *Induction Coils* and galvanic batteries are fully described and illustrated in the author's book on this subject, price 3*s.* Machines for generating a static current of electricity are described in *Electrical Influence Machines*, price 4*s.* 6*d.* *Electric Bells, and All About Them*, price 3*s.*, will tell how electric bells are made. *The Electro-plater's Handbook* (price 3*s.*) will give instruction in making apparatus and solutions used in electrolytic experiments. Dynamos, Telephones, Electromotors, Galvanometers, and other electrical instruments are described and illustrated in *Electrical Instrument Making for Amateurs*, price 3*s.*; *Electricity in our Homes and Workshops*, price 5*s.*; *Electro-Motors: How Made and How Used*, price 3*s.*; and the *Telephone Handbook*, price 3*s.* 6*d.*

When the cost of books and of instruments is likely to exceed the means of any one experimenter, it will be advisable for several persons to form a club or class for amusement, and purchase the books and material from a common fund, to which all subscribe. Clergymen, schoolmasters, and others interested in the education and welfare of the youth in our country districts, could do good service by organizing such clubs. The author hopes that the members of such clubs will not be con-

tent to merely find amusement for leisure hours in performing the experiments mentioned in this book, but will go on from this to something higher, filling the mind as it expands with useful knowledge, and seeking to know the why and the wherefore of all the observed results of those experiments.

As aids to the study of Magnetism and Electricity as a science, I can highly recommend Maycock's "First Book on Electricity and Magnetism," price 2*s.* 6*d.*, and Bottone's new book on the same subject, both published by Messrs. Whittaker & Co.

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ELECTRICAL EXPERIMENTS.

CHAPTER I.

EXPERIMENTS WITH MAGNETS.

§ 1. **Magnets and Magnetism.** A magnet is a substance having the power of attracting iron to itself through air-space, and adhering to iron by the same power of attraction. This power is named magnetism. Its cause is not known; its nature, so to speak—that is, what its composition may be—is but faintly understood even by the high priests of science; but its mode of action and the laws which govern this action, are more clearly known, and the knowledge is widely distributed.

Magnets may be divided into two classes:—1. Natural magnets. 2. Artificial magnets. The latter may be subdivided into two more; viz., (*a*) Permanent magnets, and (*b*) Electro-magnets. *Natural magnets* are masses of magnetic iron ore found abundantly in Sweden and Norway, and widely distributed through other parts of the world in the older geological formations. Its chemical composition may be expressed by the formula $Fe_3\,O_4$, that is to say, there are three atoms of (*ferrum*) iron combined with four atoms of

oxygen to form a molecule of the ore. Its property of attracting iron was known to men in early ages of the world, and is said to have been discovered in Magnesia, a district in Asia Minor, its name being derived from this discovery. The name of lodestone has also been

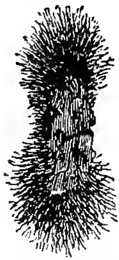


Fig. 1. Lodestone.

given to it, because of its property of placing itself with its ends pointing north and south, when suspended by a filament and free to move, the name being derived from the Saxon word "*lœdan*," meaning "to lead," because this stone leads or guides the way to the north. *Permanent artificial magnets* are masses of steel made magnetic by charging them with magnetism, and *Electro-magnets* are masses of iron made magnetic by the inductive influence of an electric current passing through wire wound over and around them. In subsequent sections of this chapter we shall illustrate by means of experiments some of the wonderful effects of magnetism.

§ 2. **Experiments with the Lodestone.** As some of my readers may have specimens of magnetic iron

ore, named lodestones, and may wish to try some simple experiments with the specimens, I will give a few hints for this purpose. Specimens are sometimes found in cabinets of old curios, the stones being mounted in rectangular or square cases of brass or of silver, beautifully chased and furnished with a cheek and armature of iron. Many of the simple experiments detailed in subsequent sections under the heads of experiments performed with permanent magnets, may also be performed with a natural lodestone. These will not be repeated here, but will receive attention later on.

One experiment only, peculiar to the lodestone, may be here described, because it cannot be performed with any other mineral specimen. The lodestone is the only stone capable of imparting a magnetic charge to a mass of steel such as a small steel bar. This may be done in the following manner :—Procure a bar of best shear or tool steel, 4 inches in length, $\frac{1}{2}$-inch in width, and $\frac{1}{4}$-inch in thickness. Let it be ground smooth and true to give it a finished appearance, then heated to a bright red, and plunged suddenly in cold water to harden the steel. Clean the bar with a piece of emery cloth, and lay it on a level bench or table. Now take the lodestone and stroke the steel bar with one end of it, always placing the same end of the lodestone on the centre of the bar, and stroking that half only in one direction. After stroking one-half of the steel in this way for several times, reverse the ends of the bar and of the lodestone, and stroke the reverse end in a similar manner. This experiment, if carefully done, will

impart a charge of magnetism to the steel bar, and this can be proved by stirring a heap of iron filings with the bar, or sprinkling a few iron filings on the ends. If the steel has been magnetized, it will attract and hold the iron filings, as shown at Fig. 2. If iron filings

Fig. 2. Iron Filings Attracted to Magnetized Steel.

are not to hand, the experiment may be performed with iron brads, or iron tacks, or bits of iron wire.

§ 3. **Permanent Magnets.** When a piece of steel is charged with magnetism, it does not readily part with the charge, but retains the magnetic charge for an indefinite length of time. Hence, a bar of steel charged with magnetism, is named a permanent magnet. This term is generally correct for most practical purposes; but a series of observations, extending over several years, has conclusively demonstrated that the very best permanent magnets gradually lose their strength and become weaker with age. This leakage

of magnetism is nearly allied to the leakage of a static charge of electricity, as when a charged Leyden jar gradually loses its charge by leakage into the surrounding air. The close resemblance between a magnetic charge and a static charge of electricity, as shown by this tendency to leakage, coupled with the property, common to both, of possessing opposing polarities, and a capability of imparting a charge to other bodies, has led some advanced thinkers to associate the two forces of magnetism and electricity in one. Mr. Sprague says of them: "Electricity and magnetism are the same force, and are two actions of polarized molecules, manifested at right angles to each other, and both developed together. Electricity is the action which occurs *in the line of polarization.* Magnetism is the action which occurs *at right angles to the line of polarization,* and in all directions at right angles to that line. But there are some important distinctions to be noticed. Electricity is essentially a dynamic force; its nature consists in producing motion in, and transmitting energy along, the polarized chains; its static actions are only incidents of this process, dependent on the resistance offered to the completed motion. Magnetism is, on the other hand, purely static; it consists in the storing up of energy in the polarized molecules." Another distinction exists, which must be noticed here. Magnetic charge can only be taken up and retained by a few substances, such as iron, steel, nickel, and cobalt; but electric charge is capable of being received and conveyed by a larger number of substances. Soft iron can be highly

magnetized, but is not capable of retaining a magnetic charge. Hard iron will receive and retain a magnetic charge, but its capacity for receiving the charge is less than that of soft iron, and its capability of retaining the charge is less than that of steel. Nickel and cobalt are only feebly magnetic. Hardened steel, such as cast tool steel, may be highly magnetized, and will retain the magnetic charge for a great length of time, if not subjected to rough usage.

The best permanent magnets are made of the best steel, manufactured from Swedish iron, and must be equally tempered or hardened throughout. "Tungsten steel" has also been recommended for magnets. Nothing whatever is gained by having a thick magnet made of a thick steel bar. The best effects are obtainable from bars only ¼-inch in thickness, but an increase of power is obtainable from several of such bars separately hardened and magnetized, and then laid together with their like poles in contact, or separated by thin brass. The compound bar thus formed, should be bound with a brass strap or band. The total force obtainable from such a compound bar, will not, however, be equal to the sum of all their separate forces added together. For most of the experiments herein detailed, an ordinary bar magnet, 6 inches in length by ¾-inch in width and ¼-inch in thickness, will suffice. A horse-shoe magnet of the same dimensions will serve for all purposes, and extend the range of the operations. A straight 6-inch magnet will cost one shilling, a 6-inch horse-shoe magnet with keeper, will cost two

shillings, whilst 6-inch compound horse-shoe magnets

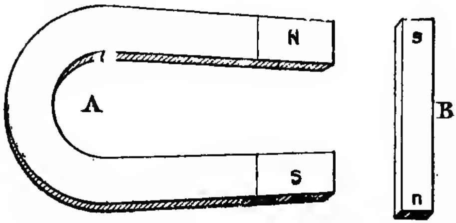


Fig. 3. A. Horse-shoe Magnet. B. Keeper.

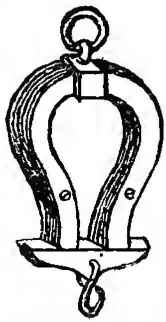


Fig. 4. A Compound Horse-shoe Magnet.

range in price from 6*s*. 8*d*. up to 15*s*., according to the number of bars in each.

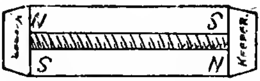


Fig. 5. Bar Magnets arranged for Storage, with Wood between, and Keepers at the end.

§ 4. **Making Permanent Magnets.** The first and

most important experiment to be performed with a permanent magnet, is, to charge another bar of steel with magnetism. It has been shown in § 2, that a bar of steel may be charged with magnetism by stroking it with a natural lodestone. This magnetized bar may be employed in magnetizing other steel bars, and these in turn may be employed indefinitely for the same purpose, without limit as regards numbers, without weakening the charge in the originals. But, although the number of magnetized bars may be increased without limit by stroking them in turn with one permanent magnet, there is a limit to the strength of the magnetic charge obtainable from a single magnet, and this limit is defined by the strength of the magnetic charge in the original inducing magnet. Hence we cannot induce a higher charge of magnetism in a steel bar, than exists in the inducing magnet employed in stroking the bar. A weak magnet may, however, be made to induce a higher charge of maguetism than its own by the following device. Procure a number of very thin strips of hardened steel, and magnetize them one by one with the weak magnet. This done, bind the whole together to form a compound magnet, and with this magnetize the larger bar of steel, which can then be made to receive a charge equal in strength to that of the compound magnet. Every bar of steel varies in its capacity for receiving a charge of magnetism, with that of other bars of steel of equal size and weight, this variation being caused by the difference in their quality and temper. The quality of the steel very largely influences its capa-

city for receiving a charge, but the temper or hardness of the steel influences its capacity still more. As a rule, a soft mildly-tempered steel is more readily magnetized than a hard steel, but the magnetic charge is not retained by the former. Every piece of steel has its limit of capacity, which is termed its saturation point, beyond which it will not retain a magnetic charge. We may induce it to take a higher charge for the moment, but the charge will soon be dissipated until the point of saturation—that is, its highest capacity—has been reached. Every piece of steel also manifests a reluctance to receive a charge. Assuming that the magnetic charge is really an alteration in the arrangement of the molecules of iron and carbon in a steel bar, by which they are brought into a condition named polarization, then, it takes time, and a number of passes to effect this alteration. If the steel is soft, its molecules are more readily altered than those of a bar of hard steel, the latter therefore manifests a higher magnetic reluctance. On the other hand, when the molecules have been altered and brought into a state of polarization, they will naturally manifest a reluctance to resume their former condition, their natural stiffness and unyielding character favouring the retention of the charge.

There are three methods by which a bar of steel may be magnetized:—1. Contact by single touch. 2. Contact by double touch. 3. Magnetization by the inductive influence of electricity.

§ 5. **Magnetizing by Single Touch.** Procure a bar of steel of any size up to 6 inches in length by ¾-inch

in width, by ¼-inch in thickness, and have it made as hard as fire and water will harden it—that is, let it be heated to a bright glowing red tint and dipped suddenly into very cold water. Place the hardened bar of steel on a table or bench, and stroke it with a permanent magnet in the following manner:—Lay the north pole end of the permanent magnet on the middle of the bar and draw the magnet slowly along to the end, then lift the magnet, lay its end again on the middle of the bar and again draw it to the end. This motion is shown by the direction of the arrow in Fig. 6. Repeat this

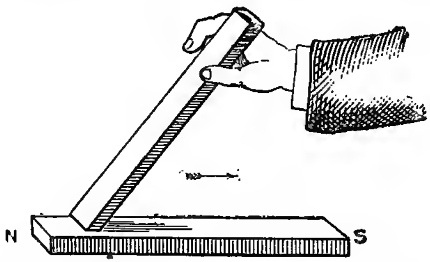


Fig. 6. Magnetizing Steel Bar by Single Touch.

some ten or twelve times. Then reverse the ends of both steel bar and magnet, and magnetize the unmagnetized end in a similar manner with the south pole of the magnet. To make sure of the poles, mark this last end of the bar with a file, this should then be the north end of the newly made magnet. This done, test its strength on a few iron nails, and its polarity by its relation to another magnet, as shown in § 9. A horseshoe magnet may be charged in a similar manner, taking

care to have the north pole of the inducing magnet on the limb intended for the south pole of the other, as shown at Fig. 8; or a bar of steel may be magnetized with a horse-shoe magnet, as shown in Fig. 7. This

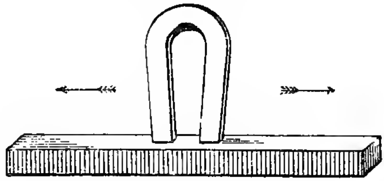


Fig. 7. Magnetizing Steel Bar with Horse-shoe Magnet.

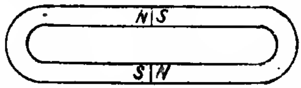


Fig. 8. Arrangement of Horse-shoe Magnets for Magnetizing and Preservation.

method of magnetizing is only suitable to small magnets below the size given above, as it only produces a feeble magnetic power. It may be employed in magnetizing needles, steel pens, and other light pieces of steel used in experiments. If a piece of unmagnetized steel is bent in the form of a horse-shoe magnet and placed with its two ends in contact with the poles of a permanent horse-shoe magnet on a plane surface, it may be strongly magnetized in the following manner:—Place a keeper made of soft iron on the bend of the unmagnetized steel, across both limbs, and draw it along over the limbs of this and the magnet, to the bend of the magnet; then lift the iron, place it again on the bend,

draw it along as before, and repeat this operation some twelve or fifteen times. Turn over both horse-shoes without separating them, and repeat the operation on the other sides. By this method, invented by Jacobi, the steel may be powerfully magnetized, it is said, some fifteen to twenty per cent. higher than by the single-touch method first described.

§ 6. **Magnetizing by Double Touch.** This method of magnetizing steel, invented by Dr. Knight in 1745, is also named magnetizing by separate touch. The bar to be magnetized, is laid on a plain surface such as that of a table or bench, and two opposite poles of two equally powerful magnets are placed on the middle of the bar, as shown at Fig. 9. The magnets are then

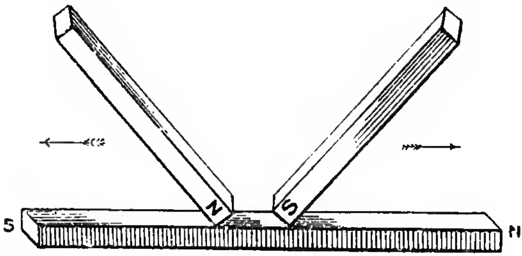


Fig. 9. Magnetizing Steel by Double Touch.

drawn in opposite directions to the end of the bar, then lifted and placed again in the centre, as shown by the direction of the arrows. This operation is repeated some twelve or more times on one face, then the bar is turned over and the operation is repeated on the other face of the bar. This method was improved by M. Duhamel

by placing the bar on the ends of two fixed magnets, as shown at Fig. 10. Steel magnetized by this method is

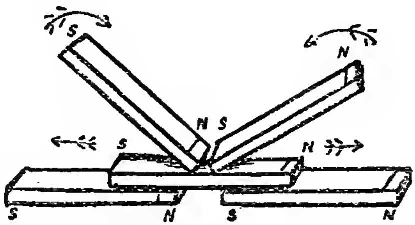


Fig. 10. Duhamel's Method of Magnetizing Steel by Double Touch.

found to be more permanently magnetic than by any of the other methods previously described. The bar to be magnetized forms a bridge across the two poles of two permanent magnets, and must be rubbed by another magnet with poles relatively arranged, as shown in the annexed figure. It should be noted that the relative positions of the poles must be maintained as shown in the figure, and the inducing magnets be inclined at an angle of from 15° to 20° to produce best results.

§ 7. **Magnetizing by Electric Induction.** If we envelop a bar of unmagnetized hard steel with a coil of insulated copper wire, and send a strong current of electricity through the wire, the electric current will induce a magnetic charge in the steel, which will permanently retain the charge after the current has ceased to flow. By repeating this operation several times, the steel will be charged up to its full capacity, and may then be said to be saturated with magnetism. Wire of

any size may be employed for this purpose, and it may be insulated with any of the insulating substances in general use for the purposes of insulation, but best results are obtained when the following conditions are fulfilled. The wire must be large enough to carry an appreciable volume of current without raising its temperature high enough to injure the insulation. As the strength of magnetism induced by such a coil is proportioned to the strength of the electric current flowing through it, the wire must be either large enough to carry a strong current, or must envelop the bar many times to multiply the effects of a weak current. The strength of the magnetic charge, is proportioned to the volume of electric current in ampères, multiplied by the number of turns in the coil. Hence, if a current of ten ampères is sent through one turn of wire wound around a steel bar, and a current of one ampère is sent through a wire making 10 turns around a steel bar, the magnetic strength induced in both will be the same. As the inductive influence of increased turns of wire becomes less when they are extended beyond three times the diameter of the core or central opening of the coil, it is advisable to have a thin insulation so as to have many turns of wire lying close to the bar to be magnetized. As No. 20 B.W.G. copper wire will carry safely 1 ampère of current, and No. 18 will carry 1·8 ampères of current, these sizes are to be recommended for magnetizing coils. Silk soaked in melted paraffin is the best insulator, but cotton insulation costs less than silk, and may be employed where the least cost is a consideration.

Although a magnet may be made by winding a quantity of insulated copper wire around a bar of steel, and sending an electric current through the coil, it is found more convenient, when making several magnets, to have a portable coil, in which the steel can be placed, magnetized, and withdrawn at will. To make such a coil, procure a strong reel or bobbin of wood having a body or core of a sufficient diameter to exceed the full size of the bars intended to be magnetized. Divide this reel into two equal parts by sawing the body in two obliquely, as shown at Fig. 11, then stick the two parts

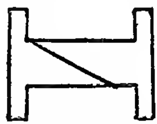


Fig. 11. Split Bobbin for Coil of Wire.

together temporarily with pitch or shoemaker's wax, and fill the reel with No. 20 silk-covered wire wound on regularly in coils side by side. Before winding on the wire, however, lay on two or four pieces of strong tape lengthwise along the body of the reel, and when the reel is full, tie these pieces of tape firmly to the coil. This will keep the coils of wire in form, after the two halves of the reel have been removed, and preserve the wire in the form of an open hank, as shown at Fig. 12. The hank should then be steeped in hot melted paraffin, and laid aside to cool. The coil of wire may be consolidated with an alcoholic solution of shellac applied

to each layer whilst winding on the wire, or with a solution of gum copal in ether, similarly applied ; or, if cheapness be desired, the reel or mandrel may be enveloped in paper to prevent the wire sticking to it, and the layers of wire may be basted with hot glue. As a

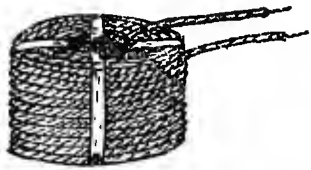


Fig. 12. Wire Coil for Magnetizing Steel.

finish, the whole coil may be painted with sealing-wax varnish.

To use this coil for the purpose of making permanent magnets, its two free ends must be connected to a powerful battery, such as two or three cells of a Grove or Bunsen battery arranged in series, or connected with some other generator of electricity having equal power. The bar to be magnetized is then placed in the coil, and moved backwards and forwards several times through the coil from end to end of the bar, at the same time rapping it smartly with a rod of iron or any other metal. The vibration of the bar under these rappings tends to hasten magnetic saturation, and secure a higher magnetic intensity. Frequent interruption of the current flowing through the coil has a similar effect, but the interruptions should take place when the bar is halfway into the coil, or, in other words, when the coil is near

the middle of the bar, and this should be its position when the magnetizing process is finished.

An electro-magnet may be employed in magnetizing steel bars, the process being the same as that of single or double touch with permanent magnets. Contact with the poles of a dynamo-electric machine will also permanently magnetize steel, and even close proximity to such a highly magnetized field will induce a magnetic charge in steel,—as the wearers of watches too often find to their cost.

§ 8. **Lines of Magnetic Force.** Although a bar of steel charged with magnetism, has the charge equally distributed through every particle, or, in other words, is quite permeated with the charge, its manifestation is chiefly confined to the two ends. These are known as the two poles, and towards these the lines of magnetic force are determined. This may be shown by placing a magnet under a sheet of smooth paper, or under a sheet of glass, and sprinkling some iron filings over its surface. On lightly tapping the paper or the glass with a quill or a straw, so as to slightly shake it and give movement to the iron filings, these will be arranged by the lines of magnetic force as shown at Fig. 13. If the paper be held over the poles of a horse-shoe magnet, the filings will be arranged as shown at Figs. 14 and 15. A close analogy is shown between the lines of a magnetic charge and that of a static charge of electricity, in the tendency to run towards the terminal ends and leak off there, and also to induce an opposite charged condition named polarity at those

terminals. This latter condition will be noted later on. The detrimental consequences of leakage from a magnet may be prevented by placing a piece of soft iron to each pole, or, in the case of a horse-shoe magnet, a piece of soft iron across the poles will suffice. This piece of iron is named the keeper, because it keeps the magnetic

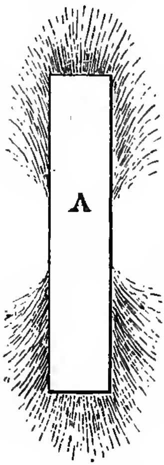


Fig. 13. Lines of Magnetic Force—Bar Magnet.

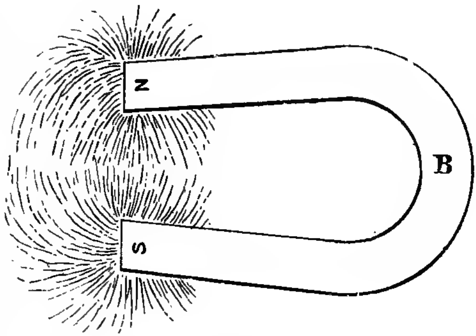


Fig. 14. Lines of Magnetic Force—Horse-shoe Magnet.

charge from leaking off. The experiment with iron filings should be varied by using a bar magnet, a horse-shoe magnet, and two bar magnets parallel to each other with their opposite poles side by side, and also with like and unlike poles end to end, as shown at Fig. 16. The experiment should also be tried with, and without keepers to the magnets. If we wish to preserve

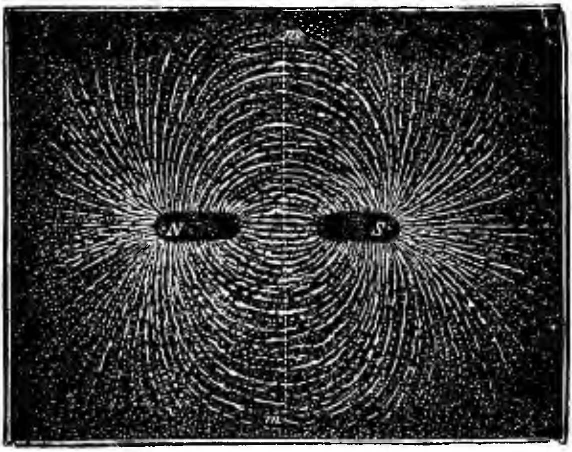
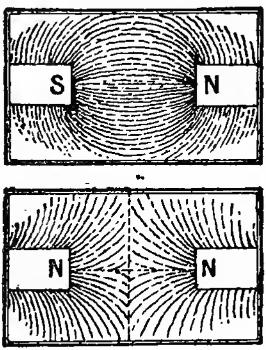


Fig. 15. Lines of Magnetic Force over the Poles of the Horse-shoe Magnet.

ATTRACTION.



REPULSION.

Fig. 16. Lines of Magnetic Force around like and unlike Poles of Magnets.

the arrangement of filings, the glass should have a thin coat of wax or of varnish.

That the magnetic charge permeates the whole of the steel bar, may be proved by magnetizing a thin piece of very brittle steel, such as a hard-tempered piece of crinoline steel or a knitting needle, then breaking this into small pieces. Each piece will be found to be equally magnetized, and each will have polar extremities, as in the whole magnet. This is shown at Fig. 17. These fragments may be used in further experiments to demonstrate the effects of heat

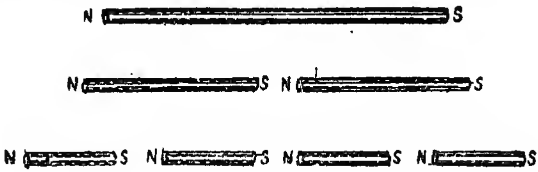


Fig. 17. Effects of Breaking a Magnet.

on magnets. As the temperature is raised, the magnetic charge will be dissipated, until, when at a red heat, no evidence of a charge is perceivable, and the piece of steel will be found to have lost it altogether. A similar effect will follow from repeatedly jarring a magnet.

§ 9. **Magnetic Repulsion.** Although the natural attribute of a magnet is to attract, it also possesses the power of repulsion. It has been shown in the preceding section, that a magnet is capable of attracting iron at both of its poles, as the iron filings cluster around both in equal quantity. Its behaviour to other

magnets, is, however, quite different. The following law governs the actions of magnets to each other:—*Poles of the same name repel; but poles of a contrary name attract one another.* That is to say, the north pole of one magnet will repel the north pole of another magnet, but attract the south pole of the second magnet, and the south poles of the same magnets will repel each other. This may be shown in the following

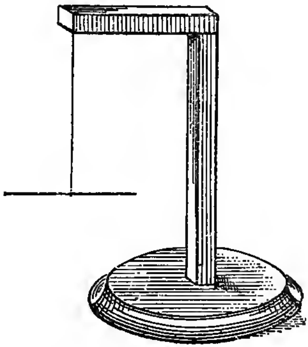


Fig. 18. Wooden Gallows.

manner:—Either make a small gallows of wood, as shown at Fig. 18, or procure a piece of stout brass wire from 12 to 15 inches in length, bend one end to form a small hook, and a longer piece of the same end to form a larger hook or arm, and fix this in a piece of wood or a suitable stand. To the small hook hang a filament of unspun silk, or a piece of soft cotton, with a small stirrup of brass wire hung to a fibre of unspun silk

attached to the lower end. A magnetized needle or a magnetized steel pen must be nicely balanced in this stirrup. If a filament of unspun or cocoon silk is employed, the needle will take up a position when at rest, pointing due north and south. If we bring the north pole of another small magnet near the north pole of the suspended magnet, it will swing away as if repelled by a breath of air. If, however, we bring the

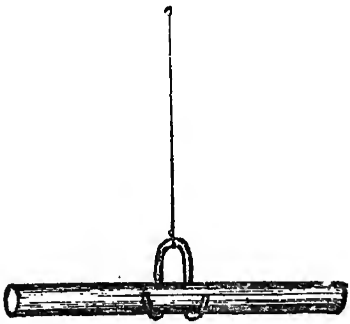


Fig. 19. Stirrup to hold Magnets, Tubes, etc., in Electrical Experiments.

north pole of the magnet in near proximity to the south pole of the suspended magnet, it will be attracted. If a large magnet is employed, the action will be strong, and may spoil the experiment by attracting the suspended magnet instead of repelling the opposite pole, and may also reverse the poles of the smaller magnet. It will be advisable to substitute an iron nail or a piece of iron wire for the magnets, and note the difference. Both ends of the iron wire will be attracted equally to

either pole of the magnet. If the iron wire is suspended in the stirrup, it will be attracted to the magnet; but if the magnet is in the stirrup, it will appear to be attracted to the iron. This will illustrate the influences of masses of iron such as that of an iron ship on the movements of the mariner's compass. If two bits of iron wire are suspended by two threads from the hook, they will mutually repel each other when a magnet is brought near them. Magnetic repulsion may also be illustrated by hanging a piece of iron, such as a key or nail, to one magnet, and then sliding the opposite pole of another magnet along over the first. When the pole of the second magnet is near enough to the suspended article, it will drop as if the magnetism of the first bar had been lost, but this is not so, the apparent loss being due to mutual repulsion.

§ 10. **Mayer's Magnetic Floating Needles.** This beautiful experiment (devised by Prof. A. M. Mayer, of the Stevens Institute, New Jersey), illustrates both magnetic repulsion and the reciprocal action of magnets. Procure a number of stout sewing needles, and an equal number of small corks, $\frac{1}{4}$-inch in diameter by $\frac{3}{8}$-inch in length. Magnetize all the needles, some with their eyes and some with their points north poles, and stick each in a piece of cork, with the eye of each needle just showing above each piece of cork, as shown at Fig. 20. Throw them all into a large bowl of water, and note their behaviour. Next get a bar magnet and pass one of its poles slowly over the floating magnets. If the north pole of the magnet is presented to them, all those with

eyes having a similar polarity will be repelled, whilst those with a south polarity will be attracted. The floating magnets will also repel or attract each other, and thus arrange themselves in sets of geometrical figures, as shown in the annexed illustration. The floating magnets may then be sorted into two bowls of water, one containing north pole needles and the other

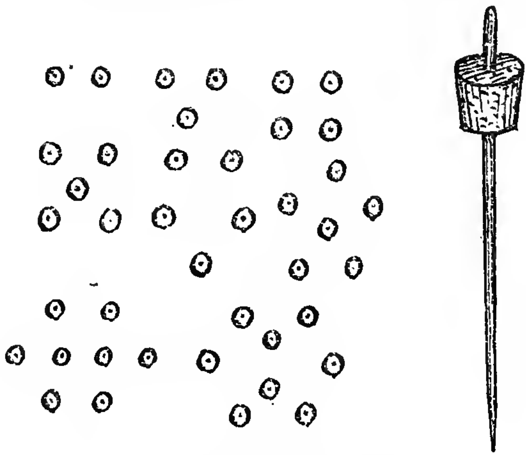


Fig. 20. Mayer's Magnetic Needles.

south pole needles, when the experiment with the bar magnet may be repeated. A bit of red sealing-wax on the north pole needles and a bit of blue sealing-wax on the south pole needles will serve to distinguish one from the other, and give additional interest to their movements.

§ 11. **Magnetic Boats, Fishes, and Birds.** A series

of very pretty parlour experiments may be performed with a moderately strong horse-shoe permanent magnet and a few pieces of iron wire properly arranged in ways now to be described. 1. With a sharp pocket-knife as a tool, carve out of cork, willow, alder, sycamore, or similar light wood, a fleet of tiny model boats, from $\frac{3}{4}$ to 1 inch in length. Insert in each boat a keel of iron wire, and bring one end of the wire over the bow to form a cut-water. Paint each little boat or ship as fancy may direct, allow the paint to dry, then float the little fleet on a bowl of water. This fleet will follow a magnet held over it or near it, and, if a bar magnet is held in a stick fashioned as a magician's wand, the movements of the whole fleet may be controlled by waving the wand over it or pointing to any part of it. If some larger models, shaped as ships and fitted with magnetized pieces of steel, be introduced into the fleet, a still further variety of movements may be effected, as the magnetic ships attract the boats or repel each other. 2. Models of swans, ducks, geese, and other aquatic fowl may also be made in wax, or carved out of wood, each being furnished with a small magnet, or with a piece of iron wire, or an iron brad. These flocks of aquatic models may be induced to follow a piece of bread or a biscuit in which a magnet has been concealed, whilst those furnished with small magnets may be made to scatter and scurry away by pointing a magnetized steel gun at them, providing the barrel of the gun be pointed near a like pole of the magnet concealed in the bird. 3. Another variation of the even-

ing's amusement may be provided by constructing a few small fish out of very thin tinned iron, such as that used in making condensed milk tins, and throwing these in the bowl of water. If the small pieces of tin are cut out with scissors or shears in the form of two halves of a fish, then bevelled, and the two halves carefully soldered together so as to make the fish hollow and water-tight, it will float, whilst others may be made not so buoyant, and others to lie on the bottom of the bowl. The models should be lacquered with suitable coloured lacquers, and, if they can be made of stamped pieces of tin to more nearly resemble fish, so much the better. These fish may be caught with a magnetized hook, or be made to follow artificial bait concealing a magnet. 4. A pleasant variation of the same experiment may be performed with stuffed birds, or models of the same. Birds made of various tinted plush and feathers, attached to frameworks of iron wire, and mounted on oscillating perches in various parts of the room, or suspended with outstretched wings from pendants or brackets, may be animated with a magnetic wand and induced to peck at biscuits concealing magnets. If ordinary stuffed birds are to be utilised in this experiment, a small piece of iron should be concealed in each head or beak, and each bird so poised as to fall back in a position of rest when the magnet has been withdrawn. This may be done by placing a small piece of lead under the tail of each bird. Insects such as bees, butterflies, and dragonflies, may be made of plush and rice-paper artistically

painted, and suspended by cocoon silk from stalks of ferns or flowers, and these may be agitated by passing the magnetic wand over them, if each insect contains a piece of iron wire, or has a framework of this wire. With a strong short bar magnet concealed beneath the fore-finger of the right hand, a semblance of magic may be imported into the entertainment.

Magic Wand. To construct a magic wand for use in these experiments, get an ebony ruler or one of ebonized wood (any other wood, or ivory, will serve the purpose), bore a hole through it, or bore a hole in each end, and either insert a long thin rod of magnetized steel, or two short bar magnets, one in each end, with a south pole at one end and a north polo at the other. These may be so arranged as to be removable at will, if desired, by unscrewing the capped end of the ruler. Otherwise, the ends of the magnets may be disguised with black enamel or black sealing-wax. The wand may have ornamental ends, and be carved or turned, or ornamented as taste may direct.

§ 12. **Magnetic Suspension.** To some persons imperfectly acquainted with magnets, it may seem possible to so arrange a magnet and a piece of iron and steel as to keep the latter suspended in the air, at a fixed distance from the magnet. As, however, one of the laws of magnetism, discovered by Coulomb, is that *magnetic attractions and repulsions vary inversely in strength as the squares of the distances from their poles,* it follows that any attractive material brought within the attractive influence of the magnet must be drawn to

it, since when once within the sphere of attraction the strength of this rapidly increases. Magnetic suspension in mid-air can only be effected by holding the attracted object back from actual contact with the magnet by means of a filament of silk or similar fibre, or by nicely balancing the iron or steel between the attractions of two magnets. Magnetic repulsion may be illustrated by means of an experiment with a magnetized needle held over a magnet by a thread of cocoon silk. If the point of the needle is given a north polarity and held over the north pole of a strong magnet, the needle will be repelled upward and appear to be floating in the air over the magnet. This experiment has been named "Mahomet's coffin," to commemorate the erroneous notion, once entertained, of Mahomet's body being placed in a steel coffin and suspended in the air between two magnets in a mosque at Medina. By attaching a thread of silk by means of wax to the underside of an iron bar and holding a strong magnet over it, the iron may be made to appear as if suspended in air by magnetic attraction.

Another interesting experiment, illustrative of magnetic suspension, may be performed with a pendulum furnished with an iron top nicely rounded on its upper end. This rounded part must be placed in contact with a strong bar magnet, from which the pendulum may be suspended by magnetic attraction, and can then be swung to and fro or made to describe a circle without loosening its hold, providing the weight is proportioned to the strength of the magnet.

When iron is in contact with a permanent magnet, its strength or power of holding up a weight is increased. This is named the portative force of a magnet. It may be tested by attaching a scale-pan to the iron keeper, and adding weights or lead shot until the keeper parts from the magnet. The magnet must be suspended vertically, and the scale-pan must be hung from a point exactly in the centre of the magnet or midway between the two poles. Magnets have been made to sustain ten or twelve times their own weight, and Jamin constructed compound magnets of thin steel plates which sustained fifteen times their own weight. These compound magnets were constructed with five or six thin horse-shoe magnets bound together with a brass band, this arrangement making a stronger magnet than a solid bar of steel the same thickness. He found, however, that the strength of these magnetic batteries was not proportioned to the number of thin magnets thus bound together. For instance, taking a thin magnet capable of holding up a three-pound weight,—by binding six such magnets together he could not get the compound magnet to hold up six times three pounds, but only fifteen pounds, the power to hold the remaining three pounds being lost in the repellent action of one magnet on another. The strongest compound magnets are those which are made of five or seven thin horse-shoe magnets of unequal length, bound together with one long magnet in the centre, the next two on each side being ½-inch shorter, the next shorter still, and so on. By this arrangement the repellent

action of like contiguous poles on each other is much reduced.

§ 13. **Magnetic Induction.** That a magnet has the property of inducing magnetism in a piece of steel, has been clearly shown in §§ 2 to 6. It also has the property of inducing a magnetic charge in a piece of iron, and converting this into a magnet whilst within the sphere of magnetic influence. An interesting experiment illustrating this property, may be performed with a number of thin iron bars, such as strips of hoop-iron, and a moderately strong horse-shoe magnet. Suspend the magnet with its poles in a vertical position, and attach one end of the first strip to one pole of the magnet. It will be seen that the iron has become a magnet by induction, for it will attract another strip of iron held to its lower end. Add another strip of iron, this also will be attracted to the first strip by magnetic induction. Add strip to strip in a similar manner, as long as that pole of the magnet will bear the weight, then add similar strips to the other pole. It will be found that a magnet can hold up a greater weight of such strips arranged in this way than it can of similar strips placed across the poles, because each strip induces magnetism in its neighbour, thus affording mutual support, and the magnetic influence is extended to a greater distance from the poles. If long intervals of time are allowed to intervene between each addition of weight in both cases, the portative strength of the magnet itself will be increased. The experiment may be varied by adding ½-inch lengths of ⅜-inch iron rod to

each other until a string of such pieces has been formed, all held together by the attraction of magnetic induction.

A neat little experiment, illustrating magnetic induction, is described in Mr. Perren Maycock's "First Book of Electricity and Magnetism,"* and is shown in Fig. 21. A permanent bar magnet is bound to a strip of iron of

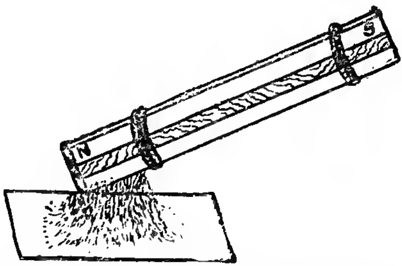


Fig. 21. Bar Magnet attracting Iron Filings by Inductive Influence on an Iron Bar.

equal size, with a strip of wood between the two bars. When thus arranged, the two metals do not touch each other, but the inductive influence of the magnet is transmitted through the intervening strip of wood to the iron, and this becomes magnetic. This is proved by sprinkling some filings on a sheet of paper, and presenting the iron only to the filings, when they will be attracted as shown in the figure.

Magnetic induction is also capable of being trans-

* Published by Whittaker & Co. Price 2*s.* 6*d.*

mitted to a long distance through wires. This is shown in the magneto call bells, employed in telegraph and telephone systems, and the magneto machines used in working the A B C telegraph instruments. Its action on a small scale may be demonstrated by a simple experiment made with a bar magnet and the magnetizing coil described in § 7. Connect the two ends of the coil to a delicate galvanometer, and plunge the magnet in the coil. At the instant of doing this, the needle of the galvanometer will be deflected, and it will be again deflected when the magnet is removed from the coil, thus showing that the magnetic impulses are taken up by the coil of wire, and the charge is transmitted to the coil of the galvanometer, where it induces a magnetic action on the needle. In the machines for ringing magneto call bells, and for working A B C telegraphs, permanent magnets are swiftly revolved near coils of wire, and the rapid succession of magnetic impulses are transmitted from these coils to similar coils wound over iron cores in the distant instruments.

This inductive action of permanent magnets, establishes the relation of magnetism to electricity, the action of both being reciprocal; for, as a current of electricity passing through a coil of wire wound over a steel bar induces a magnetic charge in the bar, so, a magnet moving in a coil of wire sets up a current of electricity in the wire.

§ 14. **Miscellaneous Magnetic Experiments.** Give a boy a horse-shoe magnet and a miscellaneous collection of metal scraps, together with clear instructions

in the use of the magnet, and he will amuse himself by the hour. The following may be suggested among many others as most likely to engage his attention.

Assorting Metal. Put into a box, or a tray, a number of brass buttons, white metal buttons, and iron buttons, all lacquered or japanned to disguise them. Also, some iron, brass, copper, and other metal brads, tacks, and nails, japanned, lacquered, painted, or tinned, to give them a uniform appearance. These should be assorted by the aid of a magnet. The magnet will pick out all the iron buttons, brads, and nails. Common tinned iron pins may be thus detected when mixed with tinned brass pins.

Jack Straws. Get some iron wire of about No. 16 gauge, cut it into various lengths of from 3 to 6 inches, and paint the pieces in various colours and tints, or furnish each with a head of coloured glass or wood. Give to each a number or value, mix them altogether in a tray or box, and proceed to pick them out as in the game of Jack Straws, using a magnet for the purpose. A few blanks of brass or of copper wire introduced among the iron wires will serve to increase the interest of the game. The game may be varied by placing a number of iron wires of various lengths in an envelope, with their ends only protruding, and drawing them one by one from the envelope with the magnet, as in "*drawing lots.*" Wire nails of various lengths may be substituted for lengths of iron wire.

Magnetic Screens. A magnet will exert its influence

on iron and steel through nearly all known substances except iron itself. Get a pocket compass, or the small galvanometer described by Mr. Bottone in "Electrical Instrument Making for Amateurs," and sold for 2*s.* 6*d.* Place this on a table, on a mantelpiece, on a mat or rug, on a slab of glass, slate, marble, porcelain, or similar stony substance, or over any other metal except iron, then place a strong magnet under the substance interposing between it and the compass. If the substance be not too thick, the needle of the compass will be influenced by the magnet in a most interesting manner. A piece of sheet iron will screen the compass from magnetic influence and alter its behaviour altogether.

§ 15. **Uses of Permanent Magnets.** Permanent magnets have been and are employed in the construction of magneto-electric machines, as indicated in the last section, and described by Mr. Bottone on pp. 15 and 175 of his book "Electric Bells, and All About Them," and also in Mr. Poole's "Practical Telephone Handbook," pp. 94–102. They are also employed in the construction of magneto-electric shocking machines, as described by Mr. Bottone in his book "Electric Instrument Making," pp. 90–99. The telephone owes its origin to a discovery of the effects of magnetic induction on a diaphragm of thin iron. Permanent bar magnets are employed in the construction of Bell telephone receivers, whilst horse-shoe permanent magnets are used in the Gower, Ader, Siemens, and some other telephone receivers. The single-needle telegraph instrument,

which has rendered such good service to all the world as a means of intercommunication between the nations, depends upon the action of a small magnet for its efficiency. This action may be thus explained. Where a small magnetized bar of steel is suspended or pivoted in a vertical position in a coil of fine wire, and a current of electricity is sent through the coil, its hollow core is magnetized, and the magnetized air space behaves toward the magnetized needle much the same as a permanent magnet, repelling like poles and attracting unlike poles of the magnetized steel. The magnetized steel, being free to move in this space, is attracted or repelled according to the polarity of the air space, this being controlled by the direction of the electric current passing through the coil. When the current is made to flow from left to right in the coil, its air core has a north polarity at the right-hand end and a south polarity at the other end. As a consequence, the north pole of the vertical steel magnet is repelled from the right-hand end of the coil, and the south pole is attracted to that end. By reversing the direction of the current, the polarity of the coil is reversed, and the magnetized needle made to swing in the opposite direction. The electric current detectors employed by telegraph linesmen and by electric bell-hangers are similarly constructed. The galvanometers, voltmeters, and ammeters described by Mr. Bottone in his book "Electrical Instrument Making for Amateurs" are constructed on similar principles, adapted to a magnetic needle poised horizontally over a coil of wire. Experiments, illustrating

these principles, will be given when considering the effects of electro-magnetic induction. Permanent magnets are also employed in electric indicators, measuring instruments, and other electric instruments.

Although these uses of the permanent magnet are of great importance to the civilised world, they may be said to occupy an inferior position to the use of it as a guide to the mariner conducting the commerce of nations across the trackless expanse of ocean which

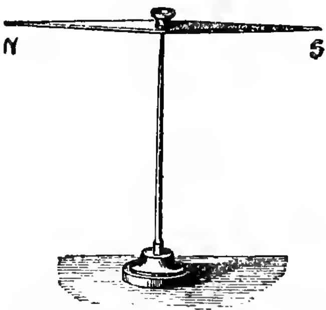


Fig. 22. Magnetized Needle balanced on a pointed Steel Pivot.

separates the continents and countries of the earth. We have already noted in § 9, that when a magnetized steel needle is suspended in mid-air by a filament, and free to move in any direction, it takes up a position pointing due north and south. This action of the magnetized needle is brought about by the influence of the earth's magnetism, exercising a directive force on the needle under the well-known law of *like poles repelling and unlike poles attracting each other.*

The earth itself is a large magnet, exerting its influence on all magnetized and magnetizable substances. The poles of this magnet are situated near the axis of its diurnal revolution. When therefore a magnetized bar is suspended above the earth's surface, one end is attracted to one of the earth's poles, and the other end to the opposite pole. The same effect follows if the needle be nicely balanced horizontally on an almost frictionless pivot, as shown at Fig. 22. This is done in

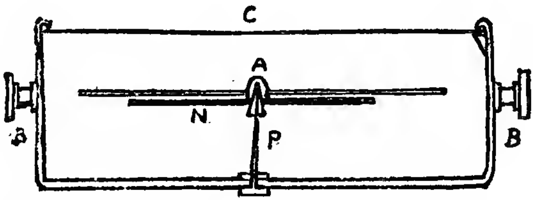


Fig. 23. Section of Compass Box.
A. Compass Card. B.B. Gimbals. C. Glass Cover. N. Needle. P. Pivot.

the construction of the mariner's compass. A magnetized needle has a hole in its centre, bushed with an agate cap, having a conical interior, and this is nicely poised on a steel point, as shown in Fig. 23.

A card or a disc of mica (A), having a diameter a little larger than the length of the needle (N), and lettered with letters indicating the various points of the horizon, is either fixed to the upper surface of the needle, with its north-seeking pole under N. of the card, and its south-seeking pole under S., or under the needle, with this free to move about it as in a small pocket compass. The whole is enclosed in a brass box,

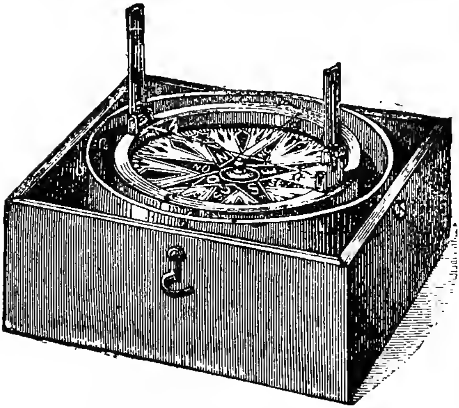


Fig. 24. Portable Boat Compass.

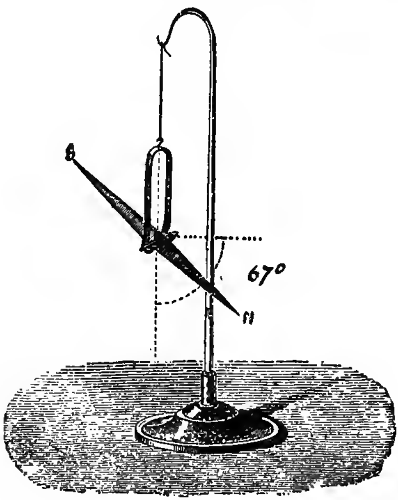


Fig. 25. The Dipping Needle.

as shown in section at Fig. 23, supported on gimbals to keep the compass in a horizontal position when the ship is in motion. The compass is placed in a box named the *binnacle* near the ship's stern and near to the steersman, who can then see, by the relative position of the ship to the points on the compass card, the direction of the ship's course.

Another use of the magnetic needle is shown in Fig. 25, which illustrates the position taken by a magnet free to move vertically, as well as horizontally. The dip and angle of the needle shows the intensity of the earth's magnetism. This varies at different points on the earth's surface, and is shown on the figure as 67° for London. This arrangement is named a "dipping needle."

CHAPTER II.

EXPERIMENTS WITH ELECTRO-MAGNETS.

§ 16. **Relation of Magnetism to Electricity.** In the preceding sections of this book, we have been able to show some of the relations which exist between magnetism and electricity. In this chapter, we shall show by means of simple experiments, a still closer relation between the two forces. To perform these, we shall require a generator of electricity such as a dynamo, or a primary battery, capable of giving an electric current having a volume of at least one ampère through a resistance of 10 ohms. This current will be furnished by 5 or 6 cells of the Bunsen, Grove, Bichromate, or Chromic Acid types, or 10 cells of the Daniell type, or one of the hand-power dynamos built to light a 5 c.p. incandescent lamp. A generator of less power will serve our purpose for some of the experiments, but all will derive additional interest from using a powerful current.

1. *The Magnetic Shell.* Every conductor of electricity is surrounded with a magnetic influence enclosing it as in a shell. An experiment to prove this may be performed with one or two cells of a battery. Get a sheet of notepaper, or any other smooth paper, and support

it on a frame or ring of wood by glueing, pasting, or gumming it thereto, then pass a piece of copper or brass wire (No. 20 gauge) through the centre vertically, and secure the ends of the wire to two metal clips

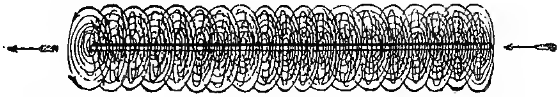


Fig. 26. Magnetic Shell around an Electric Conductor.

above and below the paper. Connect these clips in circuit with the electric generator or battery, sprinkle a few very fine iron filings on the paper, and gently rap it with a quill, penholder, or pencil. As the paper is thus made to vibrate under repeated slight raps, the

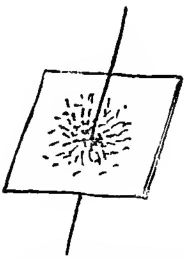


Fig. 27. Magnetized Filings around a Wire.

Fig. 28. Magnetized Filings over a Wire.

filings will arrange themselves around the wire as around a magnet, thus showing that a magnetic influence pervades the air, and surrounds the wire as a shell. By the exercise of care, the filings will show

the exact form and thickness of this shell, as at Figs. 27 and 30.

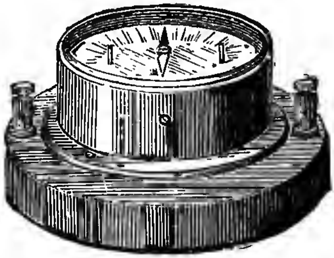


Fig. 29. Horizontal Galvanometer.

This experiment may be varied by stretching the conducting wire horizontally beneath the paper, as shown at Fig. 28, and arranging it to form various

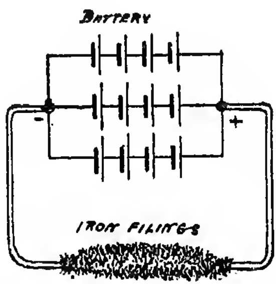


Fig. 30. Shell of Iron Filings around the Line Wire of a Powerful Electric Battery.

figures, all of which will be shown on the paper above, as the filings arrange themselves over the wire. The

wire may be bare, or may be coated with an insulating substance, without interfering with the experiment.

The magnetic shell surrounding an electric conductor is also shown by reference to Fig. 30, which illustrates how iron filings will adhere to the line wire of a powerful battery. If the line wire of such a battery is carried down through a supporting platform of thin wood or of stout cardboard, we may test the extent of the sphere of magnetic influence by means of a small pocket

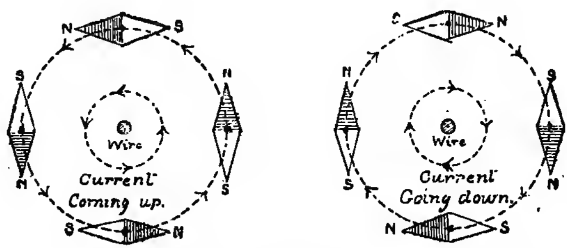


Fig. 31. Testing the Sphere of Magnetic Influence around Electric Conductors.

compass or a delicate horizontal galvanometer, when the results will be as shown at Fig. 31. On referring to this, it will be seen that the polarity of the current differs in the down line from that of the up line, and the compass needle varies its position as we move the compass.

2. *Electro-Magnetic Induction.* Procure or make a delicate horizontal galvanometer such as that described by Mr. Bottone in his book "Electrical Instrument Making for Amateurs" (Fig. 29). Also procure a few

yards of No. 22 or No. 24 gauge copper wire, and form two model telegraph lines running parallel to each other closely, side by side without actually touching. Connect the two ends of one line wire to the galvanometer, and the two ends of the other line wire to the battery. Immediately, on connecting one line with the battery, the galvanometer needle will be seen to move, and it will move again at the instant when the wire is disconnected from the battery, although the line in connection with the

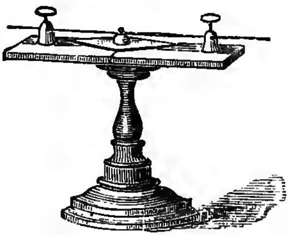


Fig. 32. Oersted's Induction Apparatus.

galvanometer does not touch the line connected to the battery. This effect is produced by the magnetic shell or halo surrounding the battery line inducing a similar condition in the neighbouring wire, much the same as a permanent magnet induces magnetism in iron or steel in close proximity to it.

Disconnect the galvanometer from the separate line and hold it close under the battery line, or better still (to prevent vibration of the needle by tremors of the hand) fix it in this position with the needle as close as it can be got to the wire, and let the needle lie in line

with the wire when at rest. To do this the line wire must be moved in line with the magnetic meridian of the earth. On connecting the line with the battery, a movement will be observed in the needle, which will deviate to right or left of the line according to the direction of the electric current passing through the wire. A pocket compass will serve this purpose as well as a galvanometer, or an apparatus to show this experiment (shown at Fig. 32) may be purchased at prices varying from 3*s.* 6*d.* to 10*s.* 6*d.* As like poles repel those of their own character, it naturally follows that one pole of the magnetic shell surrounding the wire must repel one end of the magnetic needle and cause it to swerve aside from its usual position of rest. This magnetic property of the electric current, discovered by Oersted, has been made use of in the construction of galvanometers and of telegraph instruments.

3. *Electro-Magnetic Attraction and Repulsion.* It has been shown in § 9 that the like poles of permanent magnets repel each other, whilst unlike poles have the property of mutual attraction. Herein was shown the law of a magnetic circuit, the polarized molecules of matter tending to form a perfect endless chain. Precisely the same law governs an electric circuit. The polarized molecules of two electric conductors placed side by side, attract each other when both are moving in the same direction, but repel one another when moving in opposite directions. This law, discovered by M. Ampère, may be illustrated by means of an apparatus so devised as to have one electric conductor fixed and the

other freely movable. Such an apparatus is shown at Fig. 33, named "Ampère's Stand and Rectangle," costing from 30*s.* to 50*s.*, according to finish. It consists of a polished mahogany stand, on which is fixed, at one end, a brass pillar carrying a projecting arm on top, terminating in a mercury cup; at the opposite end of the stand another brass pillar is fitted, with a brass clip arranged for adjustment to any height, and made

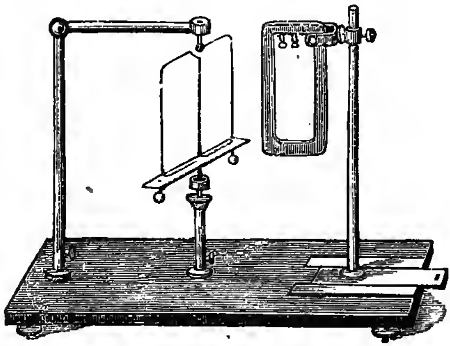


Fig. 33. Ampère's Stand and Rectangle.

to hold a flat coil of fine insulated wire named a "multiplier," the foot of the pillar being fixed to a sliding plate working in grooves, for easy adjustment to any distance; between these two pillars a shorter hollow brass pillar is fixed, in which a brass piston slides up or down, as required, and bears on the top a mercury cup. A long piece of copper wire is bent to form a double rectangular figure, as shown in the sketch, with its lower sides resting on a light strip of

wood, and one end of the wire passing through the centre of the wooden strip to the mercury cup beneath, where it is connected to a suitable pivot point. The upper end of this wire also ends in a steel needle point, which pierces a small hole in the bottom of the upper mercury cup, and makes contact with the mercury. The whole is nicely balanced by copper balls under the wooden strip, and is free to move in a circle with very little friction, whilst the double rectangle of wire is also electrically connected with the upper and lower mercury cups.

To work this apparatus we shall require a strong current from a Grove, Bunsen, or Bichromate battery of 4 cells arranged in series. Connect one pole of the battery to the long brass pillar, and the other pole to one of the binding screws on the multiplier, then connect the other screw of the multiplier by means of a piece of wire with the foot of the stout pillar. If the positive pole of the battery be connected to the foot of the long pillar, the current will traverse the right limb of the rectangle in a downward direction, and will also traverse the multiplying coil in the same direction, if the battery has been rightly connected. The effect of this uniform direction of current in both multiplier and wire will be to draw the right-hand limb of the rectangle toward the coil, when both are brought near enough by moving the clip and pillar supporting the coil. If the current is now sent in the reverse direction through the coil, the wire will be repelled.

A series of very interesting experiments with similar

apparatus is given in "Ganot's Physics," chapter iv., §§ 846–861, under the head of "Attraction and Repulsion of Currents by Currents."

4. *Diamagnetic Experiments.* The magnetic influence of a powerful electro-magnet extends beyond the immediate neighbourhood of its poles, and induces a temporary magnetic condition in other substances besides those of iron and steel. Coulomb discovered in 1802 that all bodies are more or less affected by magnetic influences. Faraday discovered in 1845 that a powerful electro-magnet had a peculiar influence on all bodies, solid and liquid, brought by him within the magnetic field,—that is, the space just in front of and between the polar extremities of the magnet. Some of these bodies were repelled and some were attracted by the magnet. These bodies were arranged by him in two classes. Those that were attracted to the magnet he named *paramagnetic* substances, whilst those that were repelled he named *diamagnetic* bodies. Paramagnetic bodies are attracted to the electro-magnet, and point *axially* like a suspended magnetic needle. Diamagnetic bodies are repelled, and point *equatorially*, that is across the axis of the magnet's bobbins. The following substances have been experimented upon, and arranged in their several classes :—

Paramagnetic Bodies. Iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, platinum, osmium, paper, sealing-wax, fluor spar, peroxide of lead, plumbago, China ink, Berlin porcelain, red lead, sulphate of zinc, shellac, silkworm gut, asbestos, vermilion,

tourmaline, charcoal, basic salts of iron, oxide of titanium, oxide of chromium, chromic acid, salts of manganese, salts of chromium, oxygen.

Diamagnetic Bodies. Bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold, arsenic, uranium, rhodium, iridium, tungsten, rock crystal, mineral acids, alum, glass, litharge, common salt, nitre, phosphorus, sulphur, resin, spermaceti, Iceland spar, tartaric acid, citric acid, water, alcohol, ether, starch, gum arabic, wood, ivory, dried matter,

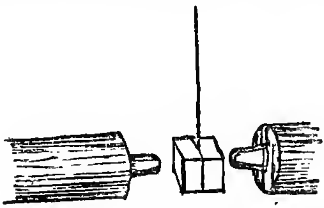


Fig. 34. Diamagnetic Experiment with Copper Cube.

fresh beef, dried beef, apple, bread, leather, fresh and also dried blood, caoutchouc, jet, turpentine, olive oil, hydrogen, carbonic acid, nitrous acid, nitric oxide, olefiant gas, coal gas.

Nitrogen is neutral to magnetic influence.

Powders, gases, and liquids are examined in thin and slender glass tubes suspended in a fibre stirrup by a thread of cocoon silk between the poles of the electro-magnet. Powders and liquids may also be examined on a watch-glass placed on flattened soft iron extensions screwed into tapped holes in the ends of the magnet cores. Conical and other forms of terminals to suit the

experiments are attached to the poles as required, in a similar manner. When liquids are being examined in watch-glasses, a diamagnetic liquid is known by its behaviour in retreating from the poles and forming a little heap, whilst a paramagnetic liquid is attracted

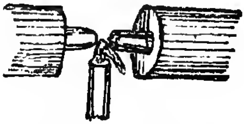


Fig. 35. Diamagnetic Experiment with Candle.

toward the poles, and becomes flattened or of concave form. Solids should be formed into cubes where practicable, and suspended by silken threads between the poles, as shown at Fig. 34. Flames and smoke may be examined by holding the flaming or smoking substance between the poles, as shown at Fig. 35. The behaviour of flames will be found very interesting, being

Fig. 36. Paramagnetic Fluid.

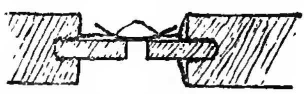


Fig. 37. Diamagnetic Fluid.

elongated, flattened, or depressed according to their position. Candle and taper flames are repelled. A record of experiments in diamagnetism will be found in "Ganot's Physics," and in "Pepper's Playbook of Science."

§ 17. **Simple Electro-Magnets.** The intimate relation between magnetism and electricity is most clearly shown by the inductive influence of the latter on soft iron, converting it into a magnet whilst under electric influence. If we take a rod of soft iron and wind over it several turns of insulated copper wire, we may convert the iron into a magnet at will by sending a strong current of electricity through the wire coil wound over the iron. A simple electro-magnet may be constructed out of an ordinary French wire nail and a yard or so of No. 24 silk-covered copper wire. Wind the wire in regular turns side by side around the nail, and in regular layers, until only a length of some 4 or 5 inches has been left at the commencing and finish ends. Connect these ends to the battery, and note the magnetic condition of the nail by hanging iron brads to its head as to the pole of a permanent magnet. If the wire is wound around a 3-inch length of $\frac{3}{8}$-in. iron rod, and about a foot or so of wire is left at each end for connection with the battery, a number of interesting magnetic experiments may be performed (as with a permanent bar magnet) whilst the wire coil is connected with the battery and a current of electricity is passing through the coil. In fact, all the experiments performable with a permanent bar magnet may also be performed with this simple electro-magnet. In addition to these, we may illustrate the fact that the iron is only magnetic whilst a current of electricity is passing through the coil. Small iron articles picked up with this magnet will be dropped instantly when the electric circuit is

broken, as when the wire is disconnected from the battery. By the exercise of a little ingenuity and skill, a magic wand may be constructed, with an electro-magnet at one end and a spring switch at the other, connection being made with the battery by means of a flexible conducting cord carrying two wires. The circuit can be completed and the electro-magnet put in action by pressing a spring in the handle.

Magnetized Steel Filings. A very interesting experiment can be performed by substituting a glass tube filled with steel filings for the iron rod last used. Get a glass tube, stop one end with a cork, fill the tube with *steel* filings, then stop the other end with a cork. Wind the insulated wire around this tube, instead of the iron rod, and send a strong current through the coil. The steel filings will then exhibit all the properties of a permanent steel magnet, even after the circuit has been broken and the tube removed from the coil, if this is done carefully so as to leave the filings undisturbed. If, however, we shake the tube, all the magnetic properties of the filings at once disappear, because then north and south poles of the particles become jumbled indiscriminately together, and these neutralise each other. This experiment has been employed by science teachers to show the bad effects of jolting and knocking permanent magnets.

§ 18. **Horse-shoe Electro-Magnets.** If a length of soft iron is bent into the form of a horse-shoe and covered with insulated copper wire, as shown in Fig. 38, it will be converted into a powerful electro-magnet when a

strong current of electricity is sent through the coil. The usual method of coiling the wire on a horse-shoe electro-magnet is as shown in Fig. 40,—that is to say, part of the wire is wound on one limb from left to right, and the rest of the wire is wound on the other limb in the opposite direction. This insures north polarity in the magnetism of one limb and south polarity in the opposite limb, and, as opposite poles attract each other, the magnetic strength of the poles is much increased

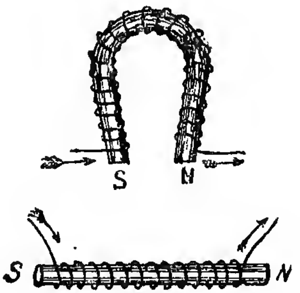
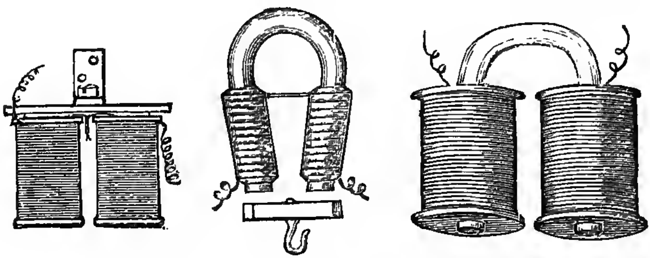


Fig. 38. Simple Bar and Horse-shoe Electro-Magnets.

by this arrangement. The polarity of either limb is determined by the direction of the electric current passing through the coil of wire wound over the limb. For instance, taking Fig. 38 as an illustration, if the current enters at S and leaves at N, S will be the south pole and N the north pole; but if the current enters at N and leaves at S, then N will be the south pole and S the north pole of the electro-magnet. The north pole is always to the left of the current when flowing in a coil of wire wound over an iron rod. This has been gra-

phically represented by imagining a boy lying on his stomach over a roller and trying to move forward. His forward movement represents the movement of the current, and his left hand then points to the north pole of the roller. If he turns round and rolls in the opposite direction, the poles are reversed. The polarity of an electro-magnet may also be determined by bringing a pocket compass or a suspended magnetic needle near the poles, when the north pole of the needle will be repelled by the north pole of the magnet, whilst its



Figs. 39, 40, 41. Varieties in forms of Electro-Magnets.

south pole will attract the north pole of the needle. Suspend two magnetized needles with like poles in front of a horse-shoe electro-magnet, and note the behaviour of the two needles. One limb of the magnet will attract one needle and the other pole repel the other needle.

Any of the experiments performable with a permanent horse-shoe magnet may also be performed with a horse-shoe electro-magnet, and similar experiments may be performed with it as with a straight bar electro-magnet. In addition to these, some interesting experi-

ments may be performed in lifting heavy weights attached to its armature, attracting the armature through space, and noting the distance under several variations of current strength. Variations may also be made in the shape and size of the magnets, and in the disposition of the wire coils wound over the limbs. It is not necessary to have an iron rod bent into horse-shoe form for double-pole electro-magnets. The two cores or limbs may be screwed into or rivetted in a heavy yoke of soft iron with the best results,—in fact, this is the general form given to it in all electric instruments in which it is employed, as in electric bells, etc.

§ 19. **Electro-Magnetic Portation.** This term is used to indicate the carrying power of an electro-magnet, —that is, its ability to pick up and carry by its power of attraction a weight attached to its armature. The portative power of an electro-magnet is limited by:—1. The saturation limit of magnetism its cores are capable of receiving. 2. The number of turns of wire wound over the cores. 3. The capacity of the wire for carrying currents. 4. The strength of the current passing through the wire coils wound over its cores.

Respecting these conditions we may note that:—1. The saturation limit of magnetism in pure soft iron is 200 lbs. per square inch. Ordinary commercial iron has a saturation limit forty per cent. below this, but increased strength of current flowing through the coils will cause iron to assume a higher limit. 2. The portative force of the electro-magnet is increased by an increased number of wire convolutions wound over its

cores, providing the thickness of these do not exceed three times the diameter of the cores, nor extend beyond four times the diameter of the cores, from their polar extremities. Short dumpy electro-magnets are stronger than long thin ones of equal weight. 3. As the portative force of an electro-magnet depends upon the strength of the current passing through its coils, multiplied by the number of coils themselves, it follows that the wire must have sufficient capacity to carry the current necessary to obtain complete saturation of the iron. The capacity of any given gauge of copper wire may be found by consulting the wire table published in "Induction Coils."[1] 4. The magnetic force developed in the core of an electro-magnet is governed by the number of ampères of current passing through its coils, multiplied by the number of wire convolutions. The magnetism set up in an iron core is, up to the saturation point, equal to the number of ampère turns coiled around it. In good soft iron it takes 5,000 ampères of electric current to saturate 1 cubic inch of iron with magnetism. If we can force 1 ampère of current through a coil of wire wound around an iron core 5,000 times, within the limits already prescribed, the core will be saturated with magnetism, since each turn carrying 1 ampère of current increases the portative force of the magnetized core. The same result is obtained from 2 ampères of current through 2,500 turns, or 5 ampères of current through 1,000 turns of wire.

[1] "Induction Coils," by G. E. Bonney, price 3*s*., published by Whittaker & Co.

Experiments with horse-shoe electro-magnets wound with various lengths and gauges of wire, may be tried, and their portative force ascertained by means of a

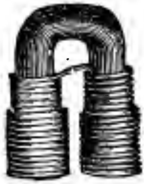


Fig. 42. Electro-Magnet with Wire heaped on the Poles.

balance scale attached to their armatures and gradually weighted. Care must be taken not to greatly exceed the limit of the carrying capacity of the wire, or its insulation will be destroyed. When it is necessary to wind more than one layer of wire on a horse-shoe magnet, the wire is first wound on two bobbins and

Fig. 43. Powerful Electro-Magnet on a Stand.

these slipped on the poles of the bent iron, or the wire may be heaped over the poles of the magnet, as shown at Fig. 42. When the portative value of an electro-

magnet is to be ascertained, it will be found convenient to suspend it to a small tripod, as shown at Fig. 44. For diamagnetic experiments, the magnet is fixed to a stand, as shown at Fig. 43.

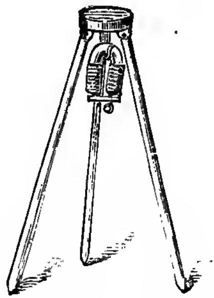


Fig. 44.. Tripod for suspending Magnets.

§ 20. **Electro-Magnetic Solenoids.** It has been shown in previous sections, that a wire conducting a current of electricity is surrounded by a shell of magnetized air. It has also been shown that iron and steel enveloped in wire carrying an electric current, both become magnetized. It has also been shown that a steel bar may be permanently magnetized by placing it in a coil of wire through which an electric current is passing. Such a coil of wire, when not occupied by a core of iron or other metal, contains a core of air, and this core becomes itself an electro-magnet, with poles similar in every respect to those of an iron core when a current of electricity is sent through the coil. A hollow coil of wire, such as that shown at Fig. 12, § 7,

constitutes an electro-magnetic solenoid. The coil may be formed and bound in the shape of a hank, as shown in this figure, or the wire may be wound over a hollow bobbin, and this fixed to a base. It is necessary to thus construct a solenoid if it is to be used in drawing a core of iron into itself. The property of all solenoids is that of a sucking action on cores of iron free to move into them. That is to say, if a core of iron is suspended in a vertical position over or under an open solenoid, and within the sphere of its attraction, the core of iron will be sucked into the coil when a sufficiently strong electric current is sent through the coil.

Experiment a. To demonstrate this sucking property of a solenoid by means of an experiment, wind several turns of insulated wire (say No. 24 silk-covered copper wire) over a hollow boxwood bobbin with thin sides, and a smooth bore of $\frac{3}{8}$ or $\frac{1}{2}$-inch; fix this solenoid to a suitable stand, and suspend close over its mouth a short rod of soft iron by means of a thin spiral spring. On sending a strong current through the coil of the solenoid, the iron will be drawn into the coil against the pull of the spiral spring. If the short iron rod is suspended beneath the coil by a filament of silk or of cotton passing through its interior, so as to have only $\frac{1}{8}$-inch of iron inside the lower mouth of the solenoid, it will be drawn up into the coil whenever a strong current is sent through the wire. The electric hammer shown at Fig. 45 (a popular toy, fully described and illustrated in *Amateur Work*, Vol. II., New Series, and in *Work*), is constructed on this principle. The hammer is con-

structured on tho model of a Nasmyth steam hammer, with a soft iron piston working in a brass cylinder wound with some three or four layers of silk-covered wire. When a current from four Bunsen cells is sent through this coil, the piston is sucked up into the solenoid, and in so doing moves a lever which disconnects the current and allows the hammer to fall. In

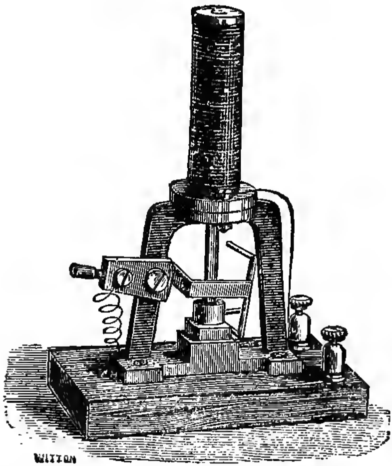


Fig. 45. Bowron's Electric Hammer.

falling it strikes the lever, and again closes the circuit, and in this way the up and down motion of the piston is ensured. This model electric hammer is sold by Mr. G. Bowron, Praed Street, London. The sucking action of solenoids has also been utilised in regulators for such electric arc lamps as the Pilsen lamp, and in the con-

struction of ammeters and similar measuring instruments.

b. The solenoid has also some other interesting properties. As might be expected, from the fact that its hollow core of air has similar polar extremities to those of an electro-magnet made of iron, these poles behave much the same as those of a magnet, the north pole of the solenoid repelling the north pole of a permanent

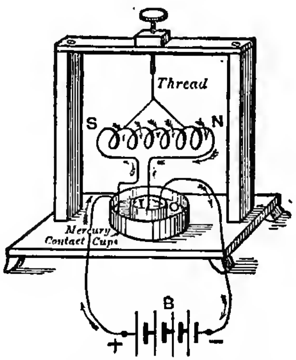


Fig. 46. Apparatus for showing the Magnetic Poles of a Solenoid.

magnet, like poles of two solenoids repelling each other; and solenoids, free to move in the magnetic meridian of the earth, place themselves with their ends pointing due north and south, thus showing that they are subject to the directive influence of the earth's magnetism.

c. *A Helix* of wire will serve the purpose in experiments with solenoids to demonstrate their magnetic

properties. A helix is a hollow spiral of wire, like a spiral spring, obtained by winding a smooth cylinder (such as a pencil or ruler) with wire, and slipping the coil of wire off when wound. Silk-covered copper wire of from No. 20 to No. 24 gauge will be found most convenient for this purpose. A helix of wire thus formed, and furnished with connecting sockets at the ends, is shown at Fig. 47. An interesting experiment may be performed, according to Professor A. Bain, with a helix thus constructed and arranged, which will serve to illustrate magnetic suspension. If a small steel perma-

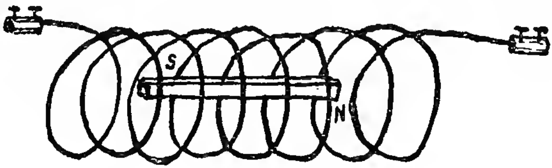


Fig. 47.

nent magnet is inserted in such a helix, and a strong current of electricity is sent through the wire, the bar magnet will rise and take up a position in the middle of the helix, as shown in the figure.

d. When such a helix is suspended to a frame, as shown at Fig. 46, with the terminals of the solenoid dipping into cups or troughs containing mercury, a current of electricity can be sent through the helix, converting it into a magnet, which is then free to move and take up a position pointing north and south, as an ordinary magnet.

e. A very interesting experiment may be easily per-

formed with a helix of fine copper wire not insulated. Connect one end of the wire helix to a horizontal arm of metal in contact with one pole of the battery, and allow the lower end of the helix to lightly dip into a metal cup containing mercury, connected to the opposite pole of the battery. On sending a current through the helix, its coils will be seen to contract, and the lower end will be drawn out of the mercury, thus breaking the electric circuit. When the current ceases to pass through the helix, its coils again expand and drop the

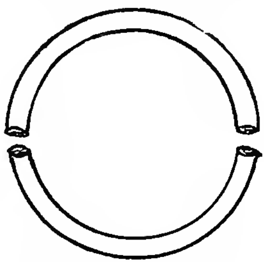


Fig. 48. Divided Iron Ring.

lower end again into the mercury cup. This completes the circuit, and the same movement is repeated, thus making and breaking the circuit by a jumping motion of the coils. This interesting movement of the helix is caused by the mutual attraction of the coils when a current is passing through them, and is utilised in constructing contact breakers for induction coils.

§ 21. **Magic Magnetic Rings**. An amusing and interesting experiment, illustrating the attractive influence of solenoids and their magnetic power, may be

performed with a magnetizing coil, as shown at Fig. 12, § 7, and an annealed iron ring divided into two equal parts with a hacksaw, as shown at Fig. 48. Thus divided, the two halves will perfectly fit each other, and this is necessary to the success of the experiment. The divided ring is then fitted together inside the wire coil and the two ends of the coil are connected with a powerful battery. The magnetized iron of the ring will keep the halves together whilst current is passing

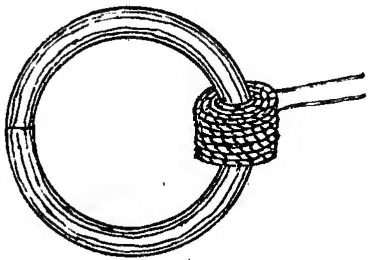


Fig. 49. Magic Magnetic Ring.

through the coil, but the whole will apparently break in pieces when the circuit is broken.

If a large iron ring—say of 1 inch round iron and 6 inches in diameter—is prepared as shown in Fig. 49, and a coil of some forty or fifty turns of No. 18 cotton-covered copper wire, some amusement may be caused by inducing a lad, not in the secret, to lift a heavy weight with the ring whilst the coil is connected in circuit with a strong battery. Whilst he is still lifting the weight, break contact with the battery, and he will

appear to have broken the ring. Or get two lads to each hold a half of the ring and gently pull, then suddenly break contact, and note their consternation at the broken ring.

§ 22. **Magic Magnetic Hemispheres.** This experiment, together with that mentioned in the last section, is a modified form of one published in 1847, and reproduced in "Electric Toy Making." The experiment is performed with two hemispheres, or cups of annealed iron, each fitted with an annealed soft iron core, one of which is furnished with a coil of wire, as shown in section at Fig. 51, thus forming an electro-

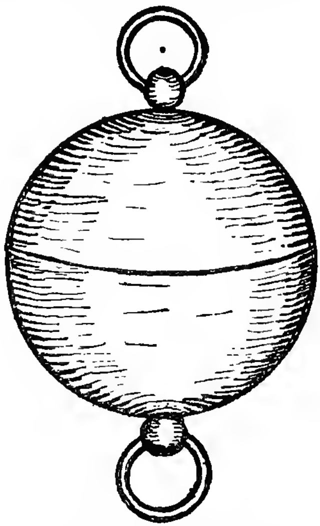


Fig. 50. Magic Magnetic Sphere.

magnet. The ends of the coil of wire may be brought through holes drilled through the crown of the hemisphere, as shown in the sketch, or brought out through two slots cut in the rims. The two hemispheres should be furnished with rings, as shown in Fig. 50, and the coil placed in circuit with a powerful battery. If every part has been well fitted, some amount of force will have to be used in pulling the two cups apart when

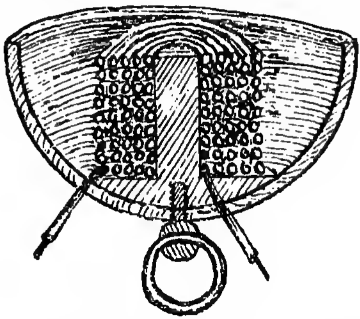


Fig. 51. Section of Magic Magnetic Hemisphere.

current is passing through the coil, but they will separate easily when the circuit is broken.

§ 23. **Uses of Electro-Magnets.** These are numerous, and would fill a long list, since a large number of electrical instruments owe their usefulness to electro-magnets. Horse-shoe electro-magnets are employed in the construction of electric bells. A full description of these is given in "Electric Bells: and All About Them," a book published by Messrs. Whittaker & Co. at the price of three shillings. Electro-magnets

in several forms are employed in the construction of dynamo-electric machines. These are briefly described by Mr. Bottone in "Electrical Instrument Making for Amateurs,"[1] and more fully in another book by the same author, on "The Dynamo: How Made and Used."

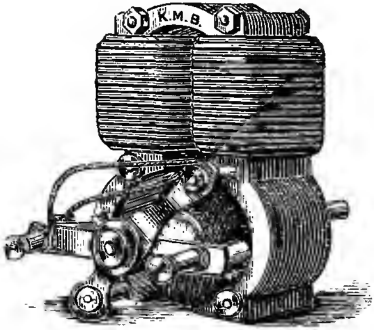


Fig. 52. King, Mendham & Co.'s Electro-Motor.

Electro-motors, are machines constructed with electro-magnets. These are described in a little volume by Mr. Bottone on "Electro-Motors: How Made and Used."[1] The cores of induction coils are electro-magnets, and also the automatic breaks of these instruments, described in the author's book on "Induction Coils."[1] The Morse sounder, which has worked a complete revolution in telegraphy since its introduction, is also an electro-magnet.

[1] All these books are published by Whittaker & Co.

CHAPTER III.

EXPERIMENTS WITH INDUCTION COILS.

§ 24. **Spark Induction Coils.** It has been shown in the previous chapter, that an electric current passing through a wire conductor, develops therein a magnetic condition which exerts an influence on the air surrounding the wire, converting it into a magnetic shell. It has also been shown that this magnetic influence is transmitted to another wire conductor running parallel to the current-carrying wire, if the two wires are placed close together without touching each other. If the current-carrying wire is wound in the form of a helix, each turn increases the electro-motive force of the current passing through the wire, because each turn magnetizes a core of air, and the magnetic influence of this is transmitted to the neighbouring turn of wire. If an insulated wire is wound over the helix of wire in the same direction, a much stronger magnetic influence is felt, so to speak, in the second or outside helix of wire than would be experienced if the two wires were merely laid along parallel in straight lines side by side. If the wire helix is wound over a core and doubled on itself so as to form a double helix, and many folds of a much finer wire is wound over this, a current of very high

tension is induced in the second wire, and a coil thus constructed, is named an induction coil. By properly arranging the wires and adding an apparatus to automatically intercept the even flow of the current in the first helix, an induction coil may be built to so enormously increase the tension of the induced current in

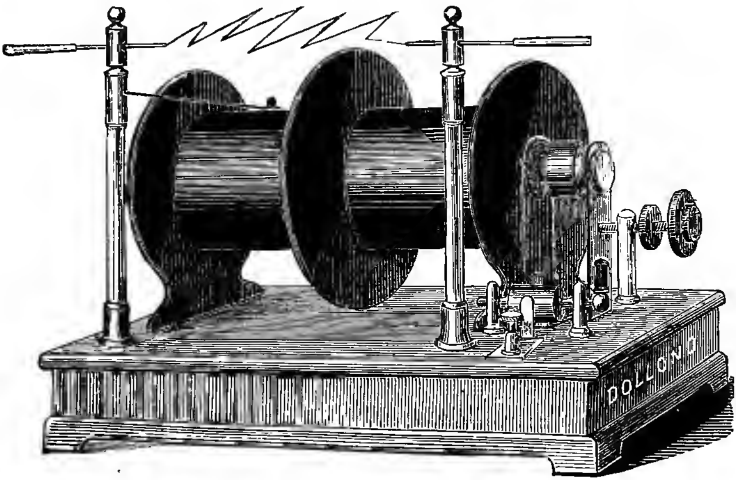


Fig. 53. A Spark Induction Coil.

the second coil as to break forth from the ends of this coil in the form of a number of snapping sparks, when the two ends are brought close together. Such an apparatus is named a spark induction coil. This has been fully described and illustrated in another book, "Induction Coils," published by Messrs. Whittaker & Co. at the price of three shillings.

§ 25. **Experiments with Spark Induction Coils.** In the book mentioned in the preceding section, the author could not, for want of space, describe the many experiments which might be performed with spark induction coils. Some of the most simple may be performed with the coil alone, or with the aid of simple home-made apparatus; but others can only be performed by the aid of other apparatus, which must be bought at a high price, or made by the amateur himself. To do the latter, he must know how to work the materials, and this knowledge can only be obtained from detailed and illustrated instructions. These are given in succeeding sections. Some of the most simple experiments with a coil giving an inch spark through air, may be performed by the aid of a Henley discharger, described in the next section.

§ 26. **Experiments with Henley's Discharger.** In the ordinary form of spark induction coil, the ends of the secondary wire are attached to two binding screws on the cheeks of the coil bobbin, or on the supporting base of the coil. Wires are led off from these screws to the apparatus in use with the coil. One such apparatus is a Henley's discharger, so named after the name of its inventor. This apparatus consists of two vertical pillars of glass or ebonite cemented into brass sockets fixed to the base-board of a coil, or to an independent base-board, at distances of 6 inches or more apart. Each pillar is furnished with a head of brass or other metal, in which is a hole holding a slide rod of brass or German silver fitted with an insulating handle

of ebonite, or (as in the best-made instruments) either a swivel joint or a ball-and-socket joint, holding a similar slide rod. The sliding rods must have insulating handles to protect the operator from violent and dangerous shocks. The tips of the rods should be made like pencil holders, to hold small pencils of metal wire, and the rods should be so arranged as to be in contact at their tips when thrust into their socket holders, or when

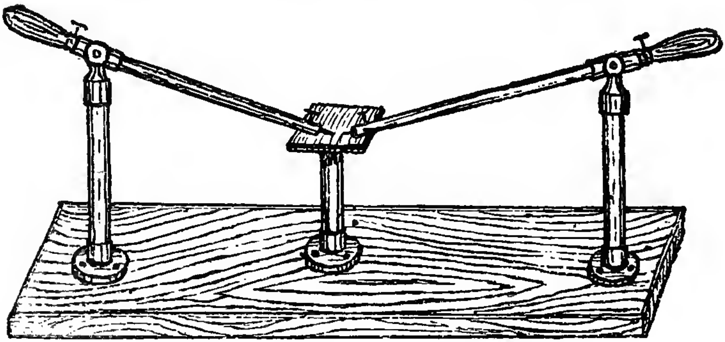


Fig. 54. Henley's Discharger for Spark Coils.

deflected at an angle over the operating table placed between them. Provision must be made for connecting these sliding rods with the terminals of the secondary wire of the coil, and this is best done in the ferrules of the handles or in the heads through which the rods slide. In best-made apparatus, a small ebonite table, 3 × 2 inches, is fixed on an insulating pillar of ebonite or glass, midway between the supporting pillars of the discharger. If the discharger rods can only slide to

and fro with a horizontal movement, this table should be fixed to a stem sliding in a hollow pillar arranged for adjustment to any height, but the table may be fixed as shown in Fig. 54, if the rods are furnished with pivoted, or ball-and-socket joints. This table is used to hold substances whilst the spark is passed through them.

1. *Deflagration of Wire.* Deflagration experiments are among the most simple that can be performed with a good spark coil and a Henley's discharger. *a.* Fix two short pieces of iron wire in the ends of the discharging rods, connect the dischargers to the secondary terminals by two lengths of copper wire, set the coil in motion, and bring the ends of the dischargers together until sparks pass freely between them. *b.* Lessen the distance between the points until one piece of iron wire becomes white hot, when it will burn vividly and emit bright sparks of burning metal. *c.* Switch the coil out of action, remove the unburnt iron wire, and substitute copper wire, then repeat the experiment, and note the difference. *d.* Procure specimens of other metal wires and repeat the experiments with them. Each different metal, and some of the different alloys, will give sparks of a different colour.

2. *Deflagration of Metal Filings.* Place a piece of ebonite, or of gutta-percha, on the insulated table between the dischargers, and sprinkle a layer of finely sifted metal filings over the surface, switch the coil into action, and bring the points of the dischargers to the edge of the filings on each side. Some of the filings

will be fired, and the zigzag spark will receive a colouring characteristic of the metal being fired. Various metal filings should be tried, and mixtures of the several metals will give a variety of results.

3. *Deflagration of Metal Foil.* Lay a smooth white card or a sheet of smooth white paper on the ebonite table, and place on it a scrap of silver foil. On bringing the points of the dischargers to the edges of the foil, it will disappear with a flash of light, and stain the paper or card. By using a new card with each, this experiment may be repeated with gold leaf, dutch metal foil, copper foil, and other thin leaf metal, the colour of the flash varying with each metal.

4. *Electric Stencils.* Place a sheet of tinfoil on the table, and in connection with one of the discharging points. Lay a sheet of note paper on the tinfoil, and bring the other discharger point to bear on the paper. Sparks will pass through the paper and perforate it with cleanly pierced, charred holes. By tracing a pattern or words on the paper with a pencil, and moving the paper under the discharger point to follow the pencil tracing, a stencil may be thus prepared. Thin card may be employed instead of paper, but more time must be allowed for the sparks to pierce the card. A portable insulated discharger connected to the secondary terminal by flexible wire cord, may be used as a stylus with advantage in this and similar experiments.

5. *Electric Stars.* *a.* Lay a sheet of glass on the table, and on this a sheet of tinfoil in contact with one of the discharger points. Set the coil in action, and

bring the other discharger point down to the centre of the tinfoil plate within striking distance. The stream of sparks will break up into diverging rays, and perform a sinuous movement over the tinfoil. *b.* Remove the tinfoil and slightly moisten the surface of the glass, then bring the points to bear on the moistened surface within striking distance. The sparks will appear to be longer, and assume a zigzag form, whilst here and there they will break up into little points of light.

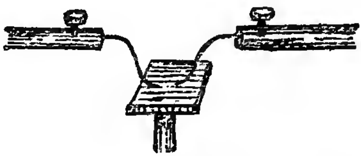


Fig. 55. Bent Wires on Ends of Fixed Discharger.

6. *Arborescent Figures.* Smoke a metal plate until its surface becomes dead black, then lay it on the table with its blackened surface uppermost, and its edge in contact with one of the discharger points. Over the metal plate, place a sheet of clean glass or of mica. Place a piece of wire in the other discharger point, and bend it so as to bring its end vertically on the centre of the glass plate, then surround it with a tiny pool of water. When the coil is set in action, this little pool will appear to grow, shooting out branches in all directions, until, after some time, the whole plate of glass or of mica appears covered with beautiful arborescent

figures. If a plate of glass and a plate of mica are procurable, they may be used alternately, different patterns being produced on plates of different material. The patterns may also be varied by employing various acid and saline solutions. This experiment has been named Dr. Wright's cohesion experiment, and has been described as such in "Intensity Coils" by "Dyer." If the discharger has not been provided with ball-and-socket joints, or pivoted joints, this and the preceding experiments may be performed with wires placed in the discharger points, and bent down, as shown at Fig. 55, or one of the rods may be removed from its supporting pillar, and held in the hand, or supported from a horizontal arm over the plate, or a portable discharger rod may be used for the purpose.

7. *Fire from Water.* *a.* Connect a length of soft No. 24 copper wire to one of the discharger rods, dip the other end into a glass of drinking water, and bring the end of the other discharging rod near the surface of the water. Vivid sparks will appear to rise from the water when the coil is in action. If a special glass is prepared by drilling a hole through the bottom, and cementing a piece of wire in the hole, and this is secretly connected with the discharger point, the result will appear magical, as if fire was obtained from water. *b.* To show that water is a bad conductor, and moist air superior to either dry air or water, make a small pool of water (in the shape of a large drop) on a plate of glass, and bring the discharger points down to the margin of the pool on opposite sides. The sparks will pass over the

surface of the water or around the margin of the pool, but not through the water, and they will cover a greater distance than in dry air. *c.* To obtain a spark through water, and observe it whilst passing through this medium, enclose two platinum wires in a thick insulation of gutta-percha well applied so as to avoid pinholes in the insulation. At one end the wires must be left bare for connection with the discharger points, or with lengths of No. 24 copper wire leading from them; the opposite ends must be covered up to a mere speck or

Fig. 56. Apparatus for Producing Sparks under Water.

tip of platinum. The two wires must now be mounted in a cork bung or in the wooden stopper of a wide-mouthed glass jar, the two covered ends of the wires being bent to within striking distance of each other; that is to say, nearly touching each other, as shown at Fig. 56. When these are immersed in water, and the coil set in action, vivid sparks will pass from one point to the other through the water. *d.* The interest felt in this experiment will be increased by enclosing the platinum wires in two bent glass tubes, and fusing the glass around their tips, instead of insulating them with gutta-percha, but this can only be done by those who

have had some experience in the manipulation of glass. Glass is almost an invisible insulator of electricity, consequently the insulation of the platinum wires will not be so apparent as when coated with gutta-percha.

8. *Oily Sparks.* *a.* Put a drop of oil on each discharger point, and bring them close together without touching. The sparks will then be intensely green, and their tint be modified by varying the distance between the points. *b.* Oil may also be employed instead of water to demonstrate the comparative conductivity of these mediums. If a drop or globule of oil be placed on a glass plate, and one of the discharger points brought close to its margin, the static charge of the coil will be manifested by the troubled surface of the oil, which will appear as if in a state of effervescence. On bringing down the other point to the opposite side of the oil-spot, this effervescence will be increased, and flashes of light will appear, but no sparks will pass. After some little time, one side of the oil spot will become dry, and this drying process will go on until only a thin film is left on the plate. This superior resistance of oil has led to its adoption as an insulator for the coils of transformers, and also for large induction coils.

9. *Superior Conductivity of Hot Air.* *a.* Arrange the discharger points to give the ordinary spark in air, set the coil in action, and bring a lighted taper near the line of sparks at one side. The stream of sparks will diverge toward the flame, and will lose some of their brilliancy. *b.* Hold the taper under the stream of

sparks, and allow them to pass through the heated air whilst the points are being slowly drawn farther apart. The superior conductivity of the heated air will be shown by the increased length of spark. Its character will also be changed from the usual violet hue and compact beady form, to a loose flame of a blue tint. *c.* Bring the points closer together, so as to obtain a fiery red spark, then hold the lighted taper in such a position as to pass the sparks through the wick, when they will become white, and of an ovate form. *d.* Raise the taper a little, and separate the points slowly. The sparks will appear to travel around the wick, and form a blue stripe in the flame. *e.* Smoke the points and bring them close together. The carbon will become incandescent, and the two points glow like white stars. *f.* Blow out the taper and hold the red-hot wick in the stream of sparks. The taper will be immediately relighted. *g.* Connect one of the dischargers with a Bunsen burner by means of a fine wire, and hold the other over the burner, light the burner, bring the point of the other discharger over the flame, and lower the point until sparks are seen to pass from it through the flame to the tube of the burner. Rub two lumps of salt together near the foot of the burner. The flame will change from blue to a brilliant yellow, and will then conduct the sparks better.

10. *Modified Forms of Sparks.* The form of the sparks from an induction coil may be modified in several ways. *a.* The stream may be bent out of its course by interposing a piece of thick gutta-percha,

when the sparks will be seen to travel around the edge of the gutta-percha. *b.* If the sheet of gutta-percha be thin, and the discharger points brought closer together, the sheet will become softened, and the sparks assume a zigzag form as they pass through it. *c.* If a piece of copper wire bent in the form of a T or L, is inserted in one discharger, and the point of the other is brought near the copper wire so as to send the sparks against the side of it, they will assume a brush-like form. *d.* By substituting a wire with a metal bead or ball at the end for the ordinary discharger point, another form of brush spark will be produced. *e.* If a small concave metal shield be soldered to a wire, and substituted for the metal ball, the spark will be again modified in form, and be accompanied by a loud snapping sound. *f.* By blowing on the stream of sparks with a mouth blowpipe, a glass tube, or a pair of bellows, a sheet of flame will be formed on the opposite side, and an appearance produced as of luminous air.

11. *Ignition Experiments.* *a.* Place a few drops of sulphuric ether on a tuft of cotton wool, and put this on the small ebonite table between the points of the dischargers. On setting the coil in action and bringing the discharger points near each other with the wool between, the ether will be at once ignited. *b.* Some lycopodium powder sprinkled over cotton wool may be ignited in a similar manner, and gunpowder may be thus exploded in small quantities. *c.* If a small tuft of gun-cotton be placed on a wire and held in the stream of sparks, it will explode with a feeble report. Only

very small quantities of these explosives should be taken at a time. *d.* A piece of phosphorus the size of a pea, placed on the back of a plate or saucer, may be similarly ignited by the stream of sparks; but I do not advise the experiment, since phosphorus is liable to be inflamed by the hand, when it will cause painful burns which heal slowly, and, the fumes of burning phosphorus are poisonous.

12. *Impulsion Sparks.* The sparks which pass between the two discharger points from an induction coil, are merely particles of air set in rapid motion by the vibratory action of the force we are pleased to name electricity. The light and heat obtained from these, is due to the friction of the rapidly impelled particles against each other, and against other substances placed in their line of action. If little or no resistance is offered to their motion, little or no heating or lighting effects will be observed. To illustrate this fact, place a small quantity of very fine boxwood saw-dust, lycopodium, flour of sulphur, or other light non-conducting powder on a plate of opal glass, and form it into a small heap or mound, the size of which must depend upon the length of spark to be used on it, since the diameter of the heap must slightly exceed the length of the spark. Place the points of the dischargers lightly in contact with the margins of the heap on opposite sides, and set the coil in action. The sparks will only set the particles of powder in motion, but will not inflame them. The vibratory action of the current can be readily traced by means of this experiment, the particles

of powder moving as if shaken by the vibrations of the glass. The unequal alternating character of the current is also clearly shown by the disposition of the dust particles. It will be seen that there is a real transference of the particles across the heap from one side to the other, but the rate of impulsion is more determined to one side and to one discharger point than to the other. Hence a gap is made in the heap as if the particles were gently blown away from the line of

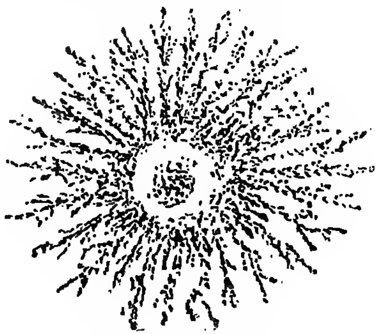


Fig. 57. Mixed Dust Figure.

current, and these particles were arranged around one point by the back eddy, whilst a clear space is left around the opposite point. Loose particles of gunpowder alone on the glass will be similarly blown aside by the current without being ignited, but when placed on cotton wool, which offers a resistance to the free movement of the particles, the friction causes heat, and this explodes the powder.

13. *Lichtenberg's Electric Dust Figures.* The mechanical effects of electric impulses may be illustrated by means of vermilion and sulphur dust, and a cake of

Fig. 58. Negative Dust Figure.

resin or of wax, or a plate of ebonite or of glass. An iron point connected with one discharger of a coil is held over the cake of resin placed on the operating table in connection with the other discharger, and the

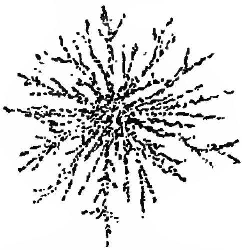


Fig. 59. Positive Dust Figure.

cake is thus charged with electricity. Some vermilion and flour sulphur is then placed in a muslin bag, and the mixed dust shaken on the electrified cake. As the

dust becomes electrified by friction when shaken from the bag (the sulphur positively, and the vermilion negatively), they take up separate positions on the cake, and arrange themselves in beautiful figures, diverse in form as they fall on a negative or a positive surface, and diverse in tint from the colours of the mixed powders. Positive spots on the cake will appear

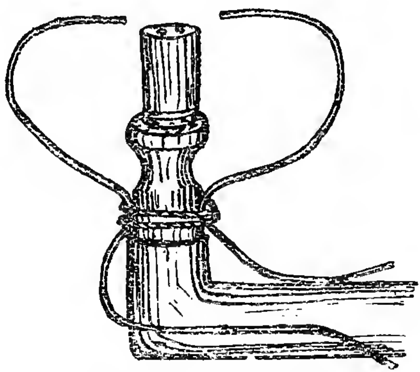


Fig. 60. Electric Gas Lighter.

yellow, and negative spots appear red, whilst in some parts we may observe a mixed spot of red and yellow, with a centre disc of red surrounded by rays of yellow. This experiment can be performed with an electric machine, or the discharge from a Leyden jar, as well as from an induction coil.

§ 27. **Lighting Gas by Electricity.** Place the coil on a table under a gas-burner, and convey two insulated wires (ordinary electric bell wires) from the secondary

terminals of the coil to the burner. Lay bare about 2 inches of the ends near the burner and bend them in the form of two horns, with their points within striking distance of each other, as shown at Fig. 60. Test this arrangement before turning on the gas, and arrange the points so as to have a good stream of sparks passing between them. On turning the gas-tap the gas will be lit by the sparks passing between the two wire points on each side of the burner. This arrangement, modified in some of its details, enters into the construction of electric gas-lighters. Care must be taken to keep the conductors insulated from each other, and, if the gas-lighter is to remain as a permanency, the discharging points should be of platinum wire.

Electric Pistol. Get a 6-inch length of $\frac{3}{4}$-inch brass tube, nicely smoothed and polished inside and outside. Mount this firmly on a pistol stock, furnished with trigger and bow complete for the sake of appearance. Drill a $\frac{1}{4}$-inch hole vertically through the brass barrel on top near the stock, and bush this with ivory fitted with a small binding screw furnished with a platinum tip. A similar hole must be drilled through the barrel beneath the stock, and this also fitted with a binding screw tipped with platinum. The two tips of platinum must come near to each other inside the barrel, but must not touch. Fit a cork to the mouth of the barrel as in an air toy pistol. Hold the mouth over a gas-burner, turn on the gas a little so as to fill the barrel with a mixture of gas and air, then securely cork the mouth. Connect two insulated wires from the secondary of an induction

coil to the binding screws above and below the barrel, and set the coil in action. A spark will pass between the platinum-tipped screws, fire the mixture of gas and air, and the consequent explosion will blow out the cork. A model mortar or a model cannon may be similarly fitted for this experiment, as shown at p. 167. A device based on this experiment has been employed to fire the explosive mixture of gas and air in gas engines.

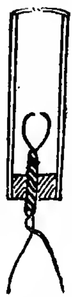


Fig. 61. Electric Fuse.

§ 28. **Electric Fuses.** In § 26, Experiment 11, we saw that the spark from an induction coil could be used to fire gunpowder, and the thought naturally occurred, why not employ a current of electricity to fire heavy guns, and explode charges of gunpowder, dynamite, gun-cotton, etc., in large blasting operations? This has been done on a large scale for many years past, and many devices, named electric fuses, have been invented and patented for the purpose. It is not my intention, in a work of this kind, to describe even a small number

of the many electric fuses that have been invented, but I will give some idea of the principles of their construction, and show how some two or three varieties may be made by the amateur for purposes of experiment.

Electric Cartridge. Get a 3-inch length of india-rubber or gutta-percha tube, or make a strong paper tube and coat it with shellac varnish, india-rubber varnish, or some other water-resisting compound, or in some other way make a water-tight tube capable of holding a charge of gunpowder. Next get two 4-inch lengths of guttapercha-covered No. 18 copper wire, twist them together to form a cable, and fit this halfway into a rubber, gutta-percha, or other water-tight plug fitting into the end of the prepared cartridge case. Separate and clean both ends of the wires from gutta-percha and bend one end as shown in Fig. 61, that is in the form of a pair of horns, with the two ends nearly touching. Place this part of the cable in the cartridge case, fit the plug in tight, then make it water-tight with varnish. Fill the case with gunpowder, and close the open end with a water-tight plug of gutta-percha, coated with india-rubber varnish. When the cartridge has been made quite water-tight, spread the two free ends of the wires outside, solder them to two longer wires coated with gutta-percha, and cover the joints with some water-resisting varnish. The cartridge is now ready, and may be exploded in a pond by connecting its wires with an induction coil, as the high-tension current will cause sparks to pass between the ends of the wires in the cartridge and fire the powder.

Statham's Fuse. An imitation of this useful fuse may be made by constructing a cartridge case as for the preceding experiment, but with the wires inside slightly modified. Procure a 6-inch length of No. 20 electric bell line wire, with an inner coating of vulcanised rubber, double this on itself, leaving a small loop or eye at one end. Remove the outer coating from this loop, but be careful not to injure the inner coating. Cut the wire clean in two with a pair of shears or scissors, and leave a gap of $\frac{1}{4}$-inch. Fold a tuft of gun-cotton over this gap, and over the wire still retaining the inner coating of rubber, then enclose the whole in the case and finish it as already directed.

Chatham Fuse. An imitation of this fuse may be made by soldering a very fine platinum wire across the gap made in the wire loop of a Statham fuse, all other parts being the same as previously described. This form is more suited to the continuous current from a battery than the intermittent current from a coil, since the platinum wire must be made hot by the current, and the hot wire fires the gun-cotton or fine gunpowder.

§ 29. **Decomposition Experiments.** Although the induced current obtainable from the secondary of an induction coil is intermittent and alternating, or has a backward and forward movement of unequal force and duration when the points of the dischargers are placed close together, or little resistance is interposed between them, this inequality is decreased by resistance, and the two ends of the dischargers are found to be definitely positive and negative. That is to say, the forward

movement of the undulations or vibrations from one, is stronger and more pronounced than from the other; and the result is a continuous flow of current in one direction. This is illustrated by the power of the induced current to decompose water, solutions of salts, and gases. If the alternating movements were equal, there could be no determination of the constituents of a solution in a given direction, and consequently no electrolytic action in the solution through which the induced current is made to pass. That the constituents of a solution are carried forward from one element to the other, and there broken up by electrolytic action, is shown in the following experiment.

Decomposition of Copper Solution. Dissolve a large crystal of copper sulphate in warm water—say ½-oz. of the copper salt in a teacup of water—and add to it a quantity of sulphuric acid, equal to a teaspoonful. Get two pieces of carbon — fragments of electric lamp carbon are suitable—and suspend them in the solution from wires connected to the secondary of the induction coil. On setting the coil in action, it will be seen that metallic copper has been deposited on one piece of carbon, whilst the other is unaffected. This shows that the copper salt has been carried to one side of the cup and there decomposed, or broken up into its constituent parts of metallic copper and sulphuric acid. The carbon on which the copper has been deposited is connected to the negative pole of the coil, and the opposite carbon is connected to the positive pole of the coil. Carbon has been selected because it is unaffected by the solu-

tion, and is cheap. Platinum will serve the purpose equally well; but iron, steel, and brass are liable to decompose the solution, and thus mislead the experimenter.

Decomposition of Water. Procure two 6-inch lengths of guttapercha-covered No. 18 copper wire, bare 1 inch of one end of each for connection with the coil, and ½-inch of the other ends for connection to two platinum wires 1 inch in length. Solder the platinum wires to the bared ends of the copper wires, and coat the joint with gutta-percha, or a water-resisting compound.

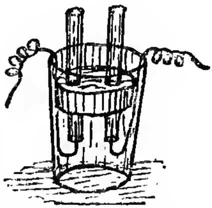


Fig. 62. Apparatus for Decomposing Water.

Bend both wires in the form of S hooks or hangers, with the platinum-tipped turn squarely formed, instead of round, and suspend them in a glass tumbler, with the squarely formed hooks inside, and the platinum tips standing vertical at a distance of 1 inch apart. Now get two glass tubes with a diameter of ¼ or ⅜-inch, insert them in a bung or a strip of cork, and place them in the tumbler over the platinum tips, with the tips standing up in the tubes about 1 inch, as shown in Fig. 62. Fill the tumbler with water strongly acidulated with sulphuric acid or with vinegar, and connect the free ends

of the wires with the terminals of the coil. On setting the coil in action, bubbles of gas will be seen to rise from the tips of each wire, and may be collected in suitable receivers placed over the open euds of the glass tubes. Oxygen gas will be given off from the positive pole, and hydrogen gas from the negative pole, these two gases forming the composition of water. The acid used in this experiment only performs the part of a superior conductor to plain water, and is not in itself decomposed by the current. With this apparatus several interesting experiments in decomposition may be attempted with various acid and saline solutions. Even with water acidulated with sulphuric acid, the effects will vary with the quantity of acid present in the water, the distance of the platinum points from each other, their position, and also their shape. The glass tubes over the points may be closed on top if desired, and the platinum points may be enclosed in glass tubes if the experimenter is skilled in the manipulation of glass; or a glass cylinder may be pierced near the bottom on two opposite sides and the points fused in these holes.

Decomposition of Iodide of Potassium. A very pretty experiment in decomposition may be performed on strips of blotting paper dipped in a starch solution and then dried. These strips should be moistened with a weak iodide of potassium solution as required, and placed on a plate of glass in contact with one of the points of a Henley's discharger. The paper should then be touched with the platinum point of the opposite discharger rod, or drawn over it whilst in contact with its surface. The

iodide of potassium will decompose under the influence of the current, and the liberated iodine will unite with the starch to form iodide of starch, and in doing so cause a purple or brown spot or mark on the paper. If the point is nicely rounded, a pattern may be traced on the paper.

§ 30. **Charging Leyden Jars from a Coil.** Leyden jars may be charged with a static current of electricity from a good induction coil. The instruments are bottles similar to pickle bottles, coated inside and outside with tinfoil, and fitted with ball-pointed rods to conduct the charge. Their construction is fully described in "Electrical Instrument Making for Amateurs," p. 71. They serve as reservoirs of static or high-tension electricity, and very powerful effects can be obtained from their sudden discharge of the stored-up electric force.

To charge a Leyden jar from a coil, place the jar on a slab of glass, ebonite, vulcanised fibre or similar insulating substance, connect one of the discharger points to the knob of the jar, and point the other to the outer coating of the jar at some little distance from it. On setting the coil in action, the jar will receive a static charge, and may be discharged in the usual manner with insulated discharging tongs.

A Battery of Leyden Jars may be charged by a large coil in the following manner:—Connect the lining of the battery tray by a wire with the secondary terminal of the coil, and connect the knob on top of the battery with one of the dischargers, the other being connected

to the coil. Place the discharger points at striking distance from each other, and set the coil in action. Sparks will pass between the discharger points, and the battery will receive a static charge from the coil. An interesting variation experiment may be tried by connecting a Leyden jar on an insulated stand as a loop, or in shunt, with a pair of dischargers. That is to say, the outer coating is connected by a wire to one terminal of the coil, and the knob of the jar to the other terminal, both discharger points being also connected to the terminals. The Leyden jar forms a supplementary condenser to the coil, and receives a static charge from the secondary coil, much the same as the tinfoil condenser receives a similar charge from the primary. This charge is discharged across the points in unison with the ordinary discharge from the secondary coil, and thus increases the length of spark and its fiery character.

Having seen how Leyden jars may be charged with electricity from a coil, we are now in a position to multiply experiments indefinitely, using the coil with this supplementary condenser (or store) for obtaining stronger effects than could be obtained from the coil alone. With the increased power at our command, sheets of glass may be perforated or broken, and the spark sent through other insulating substances.

If the coil is a large one, giving sparks of over 3 inches in length, this glass-breaking experiment may be performed direct, with the coil alone, the glass-piercing apparatus being connected in shunt with a pair of dis-

chargers, in a manner similar to that just described for the Leyden jar experiment. The glass-piercer is similarly constructed to that in use with Leyden jars, with this difference, that the piercer should be insulated up close to its point by being enclosed in a glass tube and fixed therein with shellac.

All the experiments performable with Leyden jars, detonating panes, and other apparatus for experimenting with static electricity, as described in Chapter IV., may now be performed with an induction coil.

§ 31. **Experiments with Electric Sparks in Vacuo.** In all the previously mentioned experiments with the induction coil, the induced current has been conveyed from one point to another by a conducting medium. Even when the discharger points have been separated by air-space, the intervening air has conducted the current. In the experiments about to be described, we shall see the value of this conducting medium. If we take a tube or a globe of glass, with platinum wires fused in the glass on opposite sides, and exhaust the globe entirely of air so as to obtain a perfect vacuum, the induced current will not pass between the platinum points, although these may almost touch each other. Some conducting medium must be present in the globe, but this medium may be very highly rarefied, and beautiful effects follow each variation in the rarefication of the conducting medium. Some of these are shown in the following experiments :—

1. *The Dark Tube.* Procure a tube of thin glass ½-inch in diameter and 3 inches in length, or an egg-

shaped bulb of glass, the size of a pigeon's egg, closed at oue end and having a long open stem at the other. Have two pieces of platinum wire fused into the sides of the tube or egg, with their inside points only $\frac{1}{16}$-inch apart and 1 inch of each wire outside, then entirely exhaust the tube with a Sprengel air-pump, and seal the open stem by fusing the glass with a blow-pipe flame. The entire operation should be conducted by a person skilled in glass-blowing or the manipulation of glass when heated. On connecting the outside ends of the platinum wires with the discharger points of a coil capable of giving an inch spark or more in air, the sparks will be seen to leap from one platinum wire to the other *outside* the tube, but will not pass between the points inside, although these are almost touching each other. The inside of the tube will therefore be perfectly dark: a specimen of complete vacuity.

2. *The Electric Egg.* Procure an egg-shaped bulb of thin glass, the size of a goose egg, or, in other words, an elipsoidal glass bulb, 4 inches by $2\frac{1}{2}$ inches, with short open necks at each end. One end, to form the upper part of the bulb, must be fitted with a brass collar or cap containing a leather stuffing-box, in which a metal rod or piston (some 4 or 5 inches in length) is made to work stiffly so as to form an air-tight joint. The upper end of this piston should be furnished with an ebonite knob, and below this there should be a hole and binding screw, for convenience in connecting the rod by a wire with the secondary terminal of the coil. The lower end of the bulb must be fitted with a similar

cap, furnished with a metal rod, terminating in a smooth knob 1 inch inside the bulb, and furnished with a neck and stopcock, screwing into a hollow foot for connection with the metal plate of an air-pump. By making the

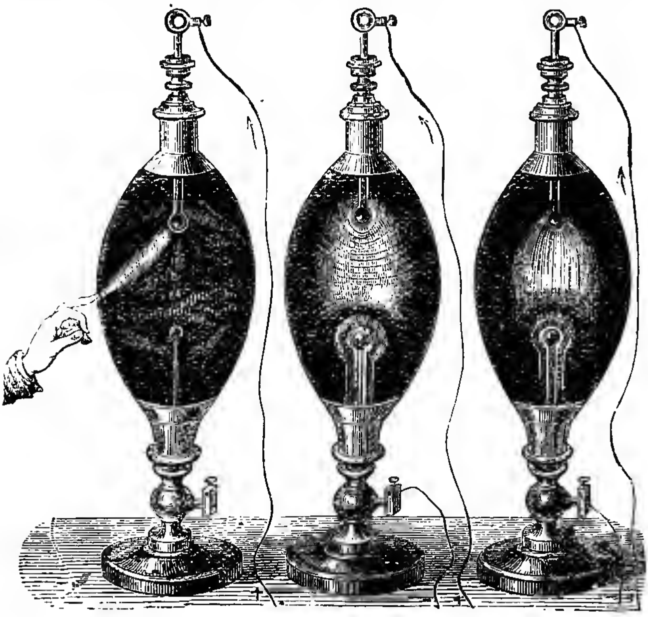


Fig. 63. Experiments with the Electric Egg. Various Striæ.

T piece of the tap thick, and drilling suitable holes therein, a binding screw may be fitted to this part, as shown in the sketch. The two caps must be secured to the glass by shellac or some other strong cement, and the joints made perfectly air-tight. The general ap-

pearance of the finished instrument is shown at Fig. 63, and the price of one in the shops is from 25*s.* to 35*s.*

By the aid of this instrument some beautiful experiments may be performed with a good induction coil, giving from one to three inch sparks or more in air. *a.* Connect the egg with the coil, press down the upper rod until the knobs of the two rods nearly touch, then set the coil in action and withdraw the upper rod little by little so as to gradually increase the distance between the poles until sparks cease to pass. Make a note of the distance over which the sparks can pass in a non-exhausted bulb. Decomposition of the air in the egg takes place as the sparks pass through it, and nitrous acid is formed if the egg is perfectly air tight. *b.* Place the instrument on the metal plate of an air-pump, and exhaust the egg of air to the fullest extent, then put it in connection with the coil, adjust the rods to obtain best results, and note the effects. *c.* Admit air again to the bulb, place it on the plate of the air-pump, connect it with the coil, and proceed in the process of exhaustion by easy stages, noting the different effects at each stage of exhaustion. The length, appearance, and colour of the sparks will undergo beautiful variations with each withdrawal of air, until a certain stage of exhaustion has been reached, when the light will fade altogether. *d.* Whilst performing the preceding experiments, we shall have noted the spark having a mauve tint when a small quantity of ordinary air remained in the bulb. Other gases will produce other tints. A small quantity of hydrogen introduced into the

bulb will give a white light when the sparks are passed through this gas. On exhausting the bulb after each experiment, and introducing other gases, we can obtain a rose or a deep orange tint from nitrogen, and a pale green from carbon dioxide. *e.* Another variety of tints and forms may be obtained by the admission of various vapours from volatile liquids, such as alcohol, ether, turpentine, etc., etc. The vapour may be introduced by placing a little of the liquid on a piece of cotton wool, and holding it under the foot of the instrument when exhausted, and opening the stopcock for a moment to admit just a whiff of the vapour. As the best effects are obtained whenever this vapour-tainted atmosphere is highly rarefied, it may be necessary to withdraw some of it with the air-pump. The bulb must be thoroughly exhausted of one vapour before introducing another. *f.* The different vapours and gases will not only show a different tint, but will also assume various stratified forms of a most interesting and beautiful character. These may be altered by placing the finger of one hand or a piece of wire near the bulb whilst the coil is in action. The glowing striæ will assume generally a pencil form and be attracted toward the finger. *g.* On approaching a strong permanent magnet to this pencil of light, its influence thereon will be immediately apparent, as the pencil will be bent aside by the influence of the magnetic force, and the declination will vary with the pole presented to the light. Experiments in great variety may be tried with different forms of permanent magnets, and also with

electro-magnets and the electric egg. *h.* If electrodes of iron are substituted for brass, the sparks will be white, those from copper, green, from silver, blue, and other metals will also influence the tint of the light in the electric egg.

3. *Gassiot's Cascade.* This beautiful experiment, the invention of M. Gassiot, was first performed with an

Fig. 64. Gassiot's Cascade.

induction coil and an ordinary glass beaker placed under the bell-glass receiver of an air-pump. It is now performed by the aid of apparatus specially constructed for the purpose. In appearance this represents a glass vase with a cover, as shown at Fig. 64, but is really a thin glass bulb blown to this form, and enclosing a glass

goblet. Its construction is peculiar, as will be seen on reference to the figure. The hollow knob of the cover has an electrode of platinum wire blown into the glass and dipping down into a funnel-shaped tube, which forms a hollow stem to the knob. This stem reaches down to near the bottom of the goblet, which rests on the shoulders of the inside of the vase. The stem of the vase is enlarged to form a bulb, and in this is inserted another platinum electrode. When the coil is connected with these electrodes, the current seems to flow, in the form of a stream of light, from the upper electrode down the funnel into the goblet, which first appears to fill with light, then overflow and stream down the sides into the lower bulb. The principles of construction here shown are adapted to other forms, and some artists in glass manipulation produce some beautiful effects by employing coloured glass in some parts of the apparatus. When the glass is stained with uranium, the stream of firo assumes a green tint, and the goblet appears to glow with a self-luminous green light, which gives it a beautiful appearance. Apparatus thus prepared may be obtained from opticians, at prices varying from 5*s.* to 10*s.* 6*d.*, according to size and finish.

This experiment obtains additional interest if performed with apparatus constructed by the amateur on lines similar to those adopted by its inventor. To construct such an apparatus, we need a good air-pump with an open top receiver, in addition to a good spark coil and accessories. The open top of the receiver should be fitted with a leather stuffing-box, through

which passes a brass rod or piston, as in the electric egg previously described. As a substitute, a well-fitting cork bung may be used, with a piece of soft leather glued to its upper surface and pierced with a hole to exactly fit a glass tube enclosing the brass rod, which must be long enough to reach the bottom of the receiver. A goblet must be next secured, and its inside coated with tinfoil to within one inch of the brim. This goblet is then placed on the metal plate of the air-pump (two bits of wire being placed under the foot of the goblet to allow free play of air whilst exhausting the receiver), and the conducting wires from the secondary coil connected to the metal rod on top of the receiver and the metal plate of the air-pump. The metal rod, with its insulating tube, should be pressed down until its rounded end nearly touches the bottom of the goblet, and the receiver be partly exhausted, when the coil may be set in action, and the pump set to work exhausting the receiver. As the air becomes exhausted and the vacuum improves, a variety of beautiful surprising effects are produced. At first a faint blue light will appear around the foot of the goblet, this will become clearer and brighter, and gradually rise upwards, increasing in brilliancy until it reaches a line level with the tinfoil coating of the goblet, this will then appear to fill from the inside, and the discharge will run over the brim, forming a splendid cascade of fire.

Any glass vessel may be substituted for a goblet, but the fiery appearance of the cascade is most effective when seen pouring over a goblet's brim.

§ 32. **Vacuum Tubes.** The beautiful effects of an induced electric current in vacuo, are best studied by means of "vacuum tubes," or "Geissler tubes" as they are sometimes named, to honourably commemorate their inventor. These tubes are made of thin glass enclosing platinum electrodes hermetically sealed by fusing the glass around them where they enter the tubes. The tubes are then partially exhausted of air, and hermetically sealed by fusing the neck of the aperture through which the air has been drawn. The vacuo in these tubes is designedly imperfect. Experience has taught their makers that a perfect vacuum is not desirable, and it has been found that the best results are obtained when the air or gases in the interior of the tubes is rarefied only to pressures which may vary from 2 to 6 millimetres. These tubes may be straight, as shown at Fig. 65, or may be in the form of two bulbs connected by a spiral tube, as shown in Fig. 68, or several such bulbs may be connected by tubes and arranged in various forms. The straight tube

Fig. 65. Appearance of Striæ in a Straight Vacuum Tube.

may also form an outer casing or protection to a great variety of devices in bent-glass tubing, snch as letters, architectural designs, figures of men, animals, birds, etc., some of which are shown in the annexed figures. A still further variety may be secured by employing stained glass, such as uranium glass, in making the tubes. Beautiful effects may be obtained from rarefied gases, and vapours of volatile liquids hermetically sealed

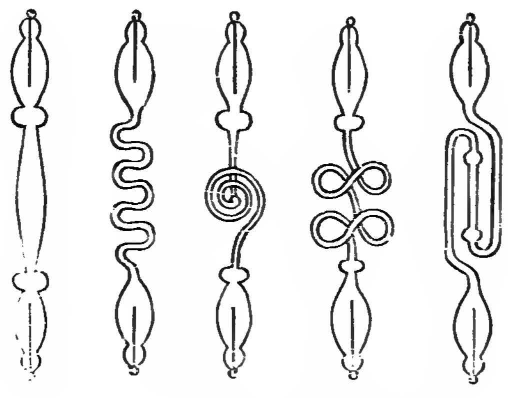


Fig. 66. Various Forms of Vacuum Tubes.

in Geissler tubes. For instance, a tube containing rarefied nitrogen will show a brush of red or rose-tinted light at the positive electrode, and a light-blue or violet halo around the negative electrode. With hydrogen the brush is crimson and the halo blue. With carbonic acid gas the brush is green arranged in rings or discs, and the glow a pretty lavender blue in

bright layers. If a tube with contracted middle, as shown in Fig. 67, is employed, the colours will be brighter in the narrow part of the tube, and this form may be utilised for illustrations in spectrum analysis. Another series of tubes may be prepared with hollow bulbs connected by short thin pipes, the bulbs containing mercury, powdered calcium, or some other substances, which are made phosphorescent by the action of the induced current and emit brilliant colours after the current has ceased. A full set of such Geissler tubes would be worth several pounds, the most intricate costing as much as two guineas each, but the simpler forms may be obtained from opticians and dealers in electrical goods at low prices, from 1*s*. 6*d*. each upward, according to size and design.

Fig. 67. Appearance of Striæ in a Contracted Vacuum Tube.

As a guide to intending purchasers, I herewith append descriptions of some forms of Gassiot tubes and the results obtainable from them.

Compound Tubes. These are small vacuum tubes enclosed in an outer sheathing of glass, the space between

the two tubes being filled with a fluorescent solution such as sulphate of quinine, which imparts a beautiful coloured margin to the stream of light passing through the inner tube.

Convoluted Tubes. These resemble the compound tubes in their construction, the sole difference being in the form of the outer casing, and the convoluted tube

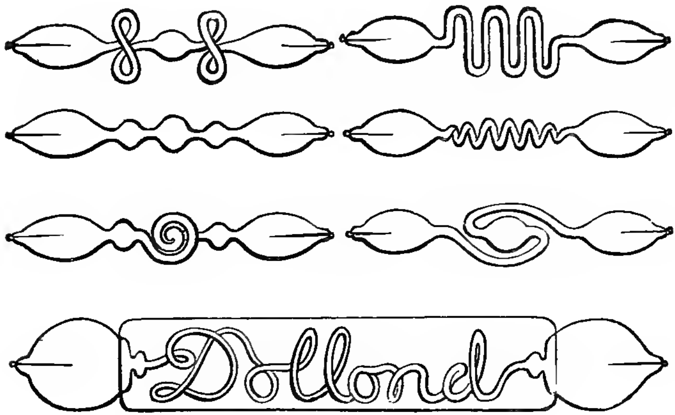


Fig. 68. Various Forms of Vacuum Tubes.

enclosed in it. The convoluted tube ends in two bulbs each fitted with platinum wires, and the outer casing is shaped to suit the form of the convoluted tube. The space in the outer casing around the inner tube and between the terminal bulbs, is filled with a fluorescent solution. The inner tube is sometimes made of tinted glass, and wrought into such forms as that of a cross, a crown, a star, or figure of flower or animal. In some,

the inner tube is twisted in the form of a spiral or zigzag, in others a compound is formed of alternating short pieces of zigzag or spiral tube, and small bulbs connected together. In some, the outer containing case is mounted vertically on a broad foot or stand, whilst in others the case is mounted in a horizontal position. The latter position is generally chosen when the outer case

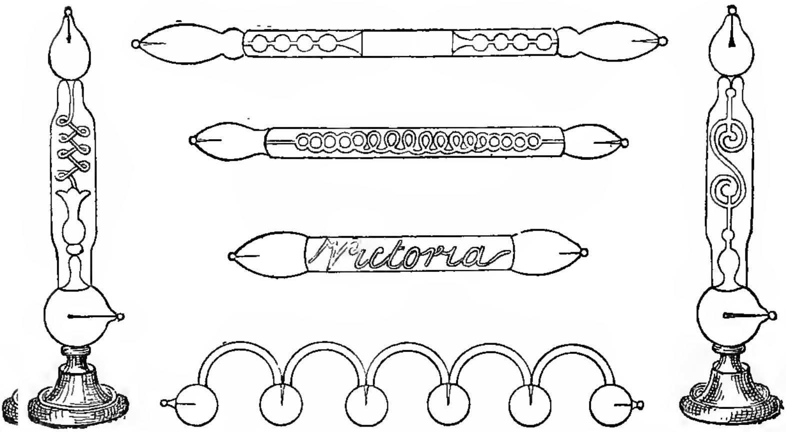


Fig. 69. Varieties in Geissler Tubes.

is thin and long and the inner tube is twisted to form the letters of a name or motto. Motto tubes in various-coloured glass have a very pretty appearance when enclosed in an outer case containing a fluorescent fluid.

Bulbous Tubes. A great variety of beautiful effects in light and colour may be achieved by employing small bulbs of glass connected together by short lengths of

small glass tube, curved to form various figures such as a simple circle, a concentric circle, a convolution of bulbs, a triangle, a pagoda, or a helix. Several bulbs may be

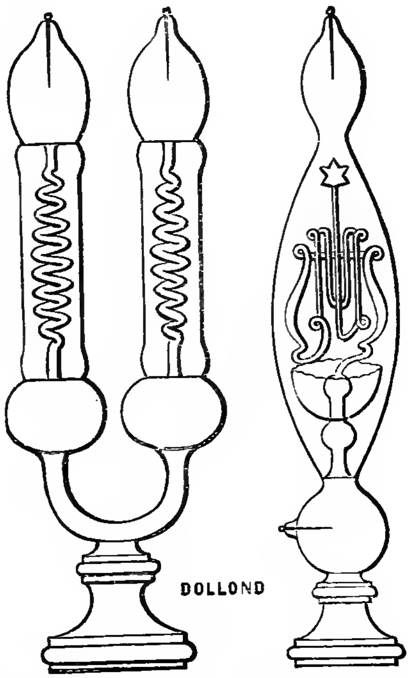


Fig. 70. Ornamental Gassiot Tubes on Stands.

connected in a row with U-tubes, and others with twisted tubes, in fact an almost endless variety of shapes are brought into requisition by the artistic glass-blower.

The Care of Gassiot Tubes. It will be easily under-

stood that such fragile articles as thin glass tubes twisted into a variety of forms, will need great care to protect them from injury. They are usually sold and kept in boxes packed with cotton wool, to which they should be consigned at once after each experiment. A very small coil, giving only $\frac{1}{8}$-inch spark, will produce luminous effects in tubes from 6 inches to 12 inches in length, but these will not be the best obtainable from such tubes. Tubes of 3 inches in length may be used for coils giving $\frac{1}{8}$ to $\frac{1}{4}$-inch sparks, but such small tubes should not be put on to large coils giving sparks of 1 inch and over this length, unless the platinum wires are very stout. Tubes of 6 inches or more, or long convoluted tubes may be worked with larger coils; but no definite rule can be laid down to guide us in adapting the length of tube to the size of coil, unless it be that of the safe carrying capacity of the platinum wires at the ends of the tubes. If these get hot, the tube should be at once disconnected. If this is not done, a portion of the wire will be volatilised, and the inside of the tube coated with deposited platinum, or the wires may be fused. It should be understood also that the thin wires fused into those tubes will not stand a very great strain upon them, and therefore should not be much bent or twisted. Should the outside loop be broken off, the tube is not entirely useless, although its usefulness is much impaired. It may still be used in experiments where a metal contact can be pressed against the ends of the tube, and in experiments with a Winter or Wimshurst electric machine.

§ 33. **Tesla's Experiments with Vacuum Tubes.** During the winter of 1891–2, Mr. Tesla astonished a large number of persons in this and other countries by a series of bold experiments with high-tension currents of electricity, among these being one with a vacuum tube illuminated by a very high-tension current passed through his own body. Not a few electricians and scientists were betrayed into utterances of astonishment, and some space was taken up in scientific journals in discussing the wonderful discovery. As the current experimented with was obtained from an alternating dynamo, it was argued that the secret lay in the frequency of alternations of the current, and only those with a high frequency could be so used. The ordinary newspapers and quasi-scientific journals of the day, were, as usual, intoxicated with the apparent marvellous discovery, one going so far as to predict that "It seems that the light of the future will be a soft phosphorescent glow, the colour of which may be arranged to suit any taste. Our rooms will be electrical fields of rapidly alternating electrical stress, in which, though nothing is sensible to the occupant, vacuum tubes and phosphorescent globes will shed their light wherever they may be placed, no connecting wires or any attention being necessary." Without attempting to depreciate the beautiful results of the experiments performed by Mr. Tesla, I must, however, point out that they are not in any way original, nor can he claim to be their discoverer. They are as old as the experiments performed by Gassiot and Giessler with vacuum tubes, and

may be repeated by any person having a spark coil and a few vacuum tubes. The experiment may be performed easily with a $\frac{1}{4}$-inch spark coil and a short vacuum tube. Put the coil on a table, and set it in action discharging sparks in the usual manner by the aid of dischargers across $\frac{1}{4}$-inch of space. Take the vacuum tube in one hand and with it touch the positive discharger rod, then with the other hand point to the other discharger. A portion of the induced current will pass through the tube, illuminating it in the usual manner, and return to the coil by the finger of the opposite hand. That this current passes through the body of the operator can be easily demonstrated by swaying the body nearer to the coil or farther away from it. When the disengaged hand is brought near the negative discharger, a decided shock is felt in the arms, and the light in the tube glows brighter. When the hand is drawn back, the light becomes fainter because of the increased resistance of the circuit due to air space. From a $\frac{1}{4}$-inch spark coil over 12,000 volts will pass through the operator's body, and with an inch spark coil the enormous tension of 50,000 volts can be borne with ease, providing, of course, that the disengaged hand is not placed in contact with the coil or any part of the apparatus. If the resistance of the circuit is kept high enough to only allow 2 milliampères of current to pass through the body, most brilliant effects can be thus obtained from vacuum tubes without danger to the operator. It will thus be seen that the results obtained do not depend upon the frequency of

the alternations in the current, since the contact breaker may work fast or slow, and yet the experiment prove a success. The experiment may also be tried with incandescent electric lamps. It is only necessary to connect one terminal of the lamp to the positive discharger, and hold the lamp in one hand whilst the other is pointed to the coil. Or the lamp may be suspended between the terminals of the coil, with equally good results. Lamps with broken filaments will do as well as or better than good lamps. Beautiful effects may be produced by using lamps with patches of tinfoil pasted on their sides.

§ 34. **Rotating Vacuum Tubes.** A very pretty experiment with vacuum tubes may be performed by rotating one of them at a high rate of speed whilst the induced current from a coil is passing through the tube. The streak of light is then multiplied into several rays, and takes the form of a star, from which appearance, and the fact that its invention has been credited to M. Gassiot, it has been named a Gassiot Star. It will be readily understood that the rotating apparatus must be specially constructed to meet the combined requirements of tube holder and rotator, and maintain electric connection with the coil. The first may be easily met by the employment of suitable metal clips to clutch and hold the tubes, and the second by a wheel or vertical arm attached to a pulley made to revolve at a high rate of speed by means of suitable wheels and bands. The third requirement is met by mounting two metal rings on the wooden hub of the

rotating wheel, and allowing two metal springs to press against these. The fixed springs are connected to the coil, and the revolving rings are connected by wires to the clips which hold the ends of the tubes. Thus the two ends of the tubes are connected through the metal rings of the hub of the rotator, with the metal springs pressing against them, and these are connected with the coil.

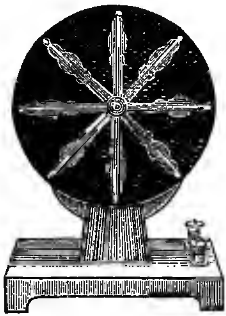


Fig. 71. Gassiot Star Hand Rotator.

The tubes may be rotated by hand or by means of a small electro-motor. The latter method is most popular, and to be highly recommended because it calls into play an interest in a useful electrical machine. Almost any form of electro-motor may be employed for this purpose. The tubes must be mounted on a stand of sufficient height to allow of their free rotation, and this stand must be so constructed as to allow of the tubes being rotated whilst they are in circuit with the coil. Power may be conveyed from the motor to the rotator,

by means of a thin band of cotton passing around pulleys on both machines; but it is usual to so construct the motor and the rotator as to have both on one stand; that is to say, the electro-motor is mounted on a high stand, and the arm or wheel to which the tube is attached, is driven direct from the spindle of the

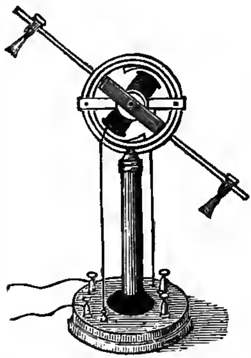


Fig. 72. Electric Ring Rotator.

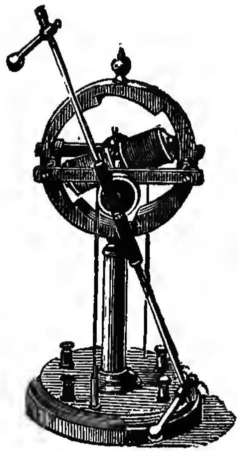


Fig. 73. Electric Ring Rotator.

motor, due provision being made for insulating the various parts, and connecting the tube in circuit with the coil. This is the better form of electro-motor for rotating vacuum tubes, since the speed of such a motor is sufficiently high without multiplying gear; and, as the work is very light, a very small model motor will serve the purpose.

At Figs. 72 to 76 are shown some forms of electric

rotators. Figs. 72 and 73 show a form usually sold by opticians at prices varying from £1 1*s.* to 25*s.* In this form there are two bobbins with iron cores wound with insulated copper wire, mounted on a spindle carrying the commutator and a pair of arms to hold the vacuum tube. These bobbins are free to revolve inside an iron ring cut into steps as shown in the sketch, the cores of the bobbins being attracted to the steps when the

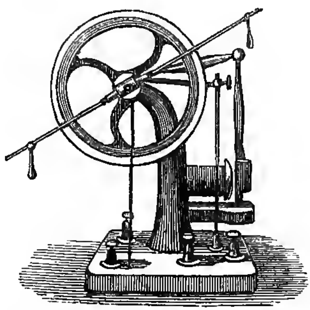


Fig. 74. Electric Rotator with Crank Motion.

circuit is closed. This form has been improved by Mr. H. Dale, who has arranged the working parts so as to have the electro-magnets fixed, and the iron ring to move around them. At Fig. 74 is shown an electric rotator with crank motion worked by a lever attached to the movable armature of an electro-magnet. This is sold for 18*s.* 6*d.*

Any small two-pole electro-motor may be employed for the purpose of rotating vacuum tubes if mounted

on a pedestal high enough to allow a free play in the carrying arms. Mr. G. Bowron has mounted a small motor of the type manufactured by him, on a pedestal in this way, as shown at Fig. 75, and claims that it is superior to the ordinary forms of electric rotation. It may be employed to rotate vacuum tubes, or by unscrewing the carrier and substituting the arms of a

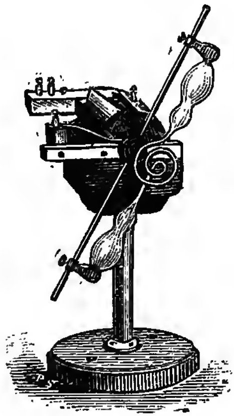


Fig. 75. Bowron's Electric Rotator.

light fan, it may be used to promote the circulation of air in a room on a hot day. The price of this motor is £1 1*s.* without the fan, or combined with the fan, £1 7*s.* 6*d.* Messrs. King, Mendham & Co. sell a small motor of this type, manufactured by them for a similar purpose. This can be altered to serve the purpose of a vacuum tube rotator, and may be worked by current

from three cells of a Hellesen or other dry battery. The price is £1 10*s*.

Those of my readers who may wish to make a small electro-motor for themselves will find ample illustrated instructions to guide them in "Electro-Motors: How Made and How Used," a handbook on the subject by Mr. S. R. Bottone, published by Whittaker & Co.

Fig. 76. King, Mendham & Co.'s Electric Fan.

§ 35. **Other Experiments with Vacuum Tubes.** The few experiments described in previous sections do not cover the whole ground of interesting experiments possible with the induction coil and vacuum tubes. Some of these possibilities are shown in a series of three articles (profusely illustrated) which appeared in the *Electrician*, vol. xxvi. pp. 323, 354, 389, under the title of "Electricity in Transitu: From Plenum to Vacuum; being the substance of a presidential address

by Professor William Crookes, F.R.S., at a meeting of the Institution of Electrical Engineers."

Fig. 77. Effect of Permanent Magnets on the Striæ in a Vacuum Tube.

The student may also find an illustrated description of experiments with vacuum tubes in "Electricity in the Service of Man," pp. 198–212, a book published by Messrs. Cassell & Co. A beautiful experiment showing the effect of permanent magnets on the striæ in vacuum tubes, taken from this source, is shown at Fig. 77.

Prof. J. J. Thomson has obtained an electric discharge through rarefied gases without the use of electrodes. A vacuum tube containing a rarefied gas had a long glass tube (containing a thread of mercury) coiled four times along it, and the discharge from a number of Leyden jars was sent through this thread. An induced discharge was caused in the vacuum tube near the line of the primary discharge,

and this did not show striæ as in the ordinary vacuum tube experiments.

§ 36. **Physiological Effects from Induction Coils.** The current delivered from the terminals of a 1-inch spark induction coil has an E.M.F. of 50,000 volts. That from a $\frac{1}{2}$-inch spark coil will be 25,000 volts; from a $\frac{1}{4}$-inch spark coil 12,500 volts; and even from an $\frac{1}{8}$-inch spark coil over 6,000 volts pressure may be obtained. If this discharge of high-tension electricity is sent through living animal tissues, such as the muscles and nerves of the human body, it causes a violent and painful contraction and relaxation of the tissues. These effects are very injurious to nervously sensitive persons, who may be most seriously injured by shocks from even a $\frac{1}{4}$-inch spark coil. Care must therefore be taken to guard any part of the body from such shocks, by avoiding an inclusion of the operator in the secondary circuit. It is best to switch the coil out of action whilst altering, adjusting, or connecting any apparatus attached to the terminals of the secondary coil. If this cannot be done, the alteration must be made with one hand only. Whilst performing experiments with the coil, no second person (except an assistant) should be allowed to handle any of the apparatus, or touch any part of the secondary circuit, so as to avoid the risk of injurious shocks. The practice of administering shocks from coils to uninitiated persons for the purpose of amusement is strongly to be deprecated, unless performed with an $\frac{1}{8}$-inch spark coil, under conditions made to prevent the full

force of the current being sent through the body. The baneful physiological effects of an electric current on human beings depends entirely on the volume of current sent through the body. Almost any person can bear a current volume of two milliampères, that is a two-thousandth part of an ampère; and if the resistances in circuit are sufficient to only allow this volume of current to pass through the body, no apprehension or fear may be entertained as to the result. For instance, if a person's whole body, having a resistance of 4,000 ohms, is placed in the secondary circuit of an $\frac{1}{8}$-inch spark coil, together with a high-water resistance of say some 10,000 ohms or over, such as that which obtains in the coin and water experiment, little or no bad effects may be feared, although a smart shock may be felt on touching the water.

This experiment occasions not a little amusement in a company of young persons. Place a silver coin in a basin of water, and dip a conductor from one of the terminals of the secondary coil into the water. A piece of brass clock chain or a metal Albert chain, connected to the end of a long piece of insulated copper wire, will serve the purpose of a conductor. The other terminal of the coil must be connected to a metal plate or other conductor, so situated as to be trod upon by any person attempting to take the coin from the basin. When the coil is in action, a smart shock will be given to the fingers of any person attempting to take the coin from the water.

Some owners of coils find a great deal of pleasure in

getting others to try their strength by grasping brass rods connected to the terminals of the secondary, and assure their victims that the shocks they receive in consequence are good for their nerves. A more mischievous heresy than this was never promulgated. Such shocks are not good for the nerves of any one, and may be positively injurious to weak persons of a sensitive temperament. For this reason I do not recommend physiological experiments with coils as a means of amusement. If any person wishes to test the

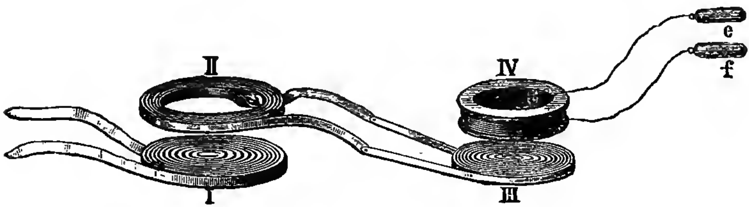


Fig. 78. Professor Henry's Induction Experiment.

physiological effects of the induced current from a coil on himself, it is only necessary to span the terminals, with the thumb on one and the little finger on the other, or rest the naked elbow on a metal plate connected with one terminal of the coil, and touch the other terminal with the fingers of the same hand. The shock received in this way will give him some idea of its effects on other people.

An interesting experiment illustrative of electro-magnetic induction was devised by Professor Henry, and may be shown by the aid of suitable apparatus.

See Figs. 78 and 79. Long strips of insulated copper ribbon were rolled into the form of coils. Coil No. 1 rested on a table in connection with a battery. Coil No. 2 was suspended close over it without touching. Coil No. 3 also lay on the table connected to Coil No. 2. Over the third coil was suspended a flat coil of very fine insulated copper wire connected with a galvanometer, or with a pair of brass handles as used in shocking coils. Interruption of the current in No. 1 coil induced a current in No. 2 coil; this current was conveyed to

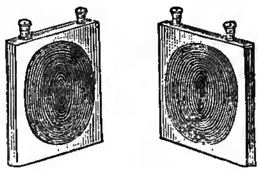


Fig. 79. Mounted Coils for use in Professor Henry's Experiment.

No. 3 coil, and induced a current in the coil of wire above it. The induced current can be shown by connecting the ends of the wire coil to a delicate galvanometer, which will show its presence by a deflection of the needle, or may be felt as shocks if a person grasps the handles connected with the wire coil. The copper ribbon coils may be placed vertically side by side or face to face with the same results. Coils for this purpose, mounted as shown at Fig. 79, are sold by Messrs. King, Mendham & Co., price 5*s*. 6*d*. per pair.

CHAPTER IV.

EXPERIMENTS WITH STATIC ELECTRICITY.

§ 37. **The Production of Static Electricity.** Although very rapid strides have been made during the last quarter of a century in our knowledge of the natural force known to us under the name of electricity, this acquisition of knowledge has only served to show the best of its students the extent of their ignorance respecting its nature. We are still floundering in a flood of unanswered questions surrounding the central one—Electricity: What is it? Hence, although advanced thinkers readily concede that the force, in whatever form it is found or however produced, is always the same thing, many of them still cling to terms which indicate a state of ignorance when men thought of electricity as a fluid, or several fluids of like character, to which the names of positive, negative, voltaic, or static were given.

The close relation of magnetism to electricity has already been shown in previous sections by means of experiments. It has been shown that the permanent magnetic condition induced in a piece of hard steel by rubbing it with another magnet, or by sending a current of electricity through a wire wound over the steel, is

identical with an electric current passing through a copper wire, both having polar extremities and behaving alike under certain conditions. In the experiments about to be described, a similar condition will be observed in the materials charged with static electricity, this term being chosen to indicate the magnetic condition of bodies other than steel. It will be seen that they behave much the same as permanent magnets, in that they have polar extremities, with the known magnetic properties, answering to the laws of like poles repelling and unlike poles attracting each other, but that they differ from steel magnets in only retaining the magnetic condition for a short time, and a readiness to give up their charge to other substances.

Static electricity is the name given to the magnetic condition of substances after they have been rubbed with other substances capable of inducing a magnetic charge. It is named static because electricity is supposed to be at rest in those charged bodies, but the term "bound electricity" is also applied to this condition. As this condition is induced by friction, it is named "frictional electricity." It is produced by suitable machines and apparatus about to be described.

§ 38. **Simple Producers of Electricity.** From the time when Thales rubbed a piece of amber with silk, and found that it then possessed the power of attraction for such light bodies as feathers, up to the present time, this attractive force has been known under the name of electricity, a word derived from *electron*, the Greek word for amber. For over 2,000

years, amber was the only substance known that could be used as a producer of electricity. Toward the end of the sixteenth century, Dr. Gilbert, a physician to Queen Elizabeth, found that all substances could be made to assume an electric condition if properly treated, and some bodies, such as sealing-wax, shellac, glass, sulphur, etc., could be made to easily assume a condition nearly resembling magnetism. If a rod of sealing-

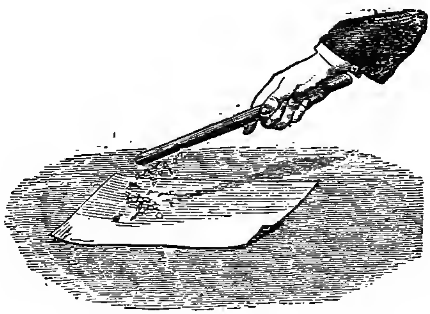


Fig. 80. Experiment to prove Attractive Influence of an Electrified Rod of Sealing-Wax.

wax be briskly rubbed for a few seconds with a piece of silk, or of cloth, or the sleeve of a coat, and then presented to small feathers, or small pieces of silk, wool, paper, and gold leaf, or bran, or similar light substances, the small particles will spring up and adhere to the sealing-wax, until they have received a full charge, when (obeying the law of magnetized bodies, of like repelling like) they are thrown off from the rod. A glass rod, a rod of ebonite, a cake of shellac, a lump

of resin, a roll of sulphur, or a cake of wax will behave in a similar manner, when rubbed with dry silk or with dry flannel, or a piece of fur, or a catskin. Metals can be made to receive a charge if they are insulated from the hand of the experimenter by glass, ebonite, or a similar non-conductor. Substances that fail to receive a charge when rubbed with one material, may be charged when rubbed by some other material.

A very interesting experiment to a party of young folks, may be performed with a piece of brown paper, whilst the party are gathered around the fire on a cold winter's evening. On warming the paper at the fire and rubbing it briskly for a few seconds with the coat-sleeve or a piece of fur, it will adhere to the wall paper of a room for a few moments, or until both are charged alike. Children will try this with varying success, and a corresponding interest in the experiment.

Another winter fireside experiment in static electricity may be performed on the domestic cat as she reclines on the hearth-rug in front of the fire. Briskly rub the two hands together, then lightly touch the fur of the cat with one finger. The fur will be seen to start, and the animal's skin will twitch as if she received a shock, which is probably the case. By stroking the finger lightly along the cat's back, her fur will lie down close to the skin along the stroked line, and leave a well-defined depression in the fur. On briskly stroking the back of the cat in frosty weather, a large quantity of electricity may be produced, of sufficient high tension to cause crackling sparks, which are plainly visible

in the darkened room. The animal suffers some discomfort on drawing sparks from her in this way, and unamiable cats are liable to resent such liberties. The same evidence of electricity may be produced on the fur or coat of other animals, but not to the same extent. It appears to be more pronounced on black or dark-coated animals than on light-coated ones. A black horse, for instance, will show streaks of electric light on its coat when groomed in a dark stable, or even when stroked with the fingers. Animals with thick fur or hair give better results than those with short coats.

§ 39. **Indicators of Static Electricity.** As we cannot proceed very far in our experiments with static electricity without some means at our command of ascertaining its existence, it will be advisable to notice here some simple apparatus for indicating the electric condition of substances under examination.

Instruments for this purpose are named electroscopes, of which there are several varieties.

1. *Pith-Ball Electroscopes.* It will be seen on referring to the previous section, that a rod of sealing-wax, when rubbed, has an attractive condition imparted to it, which is manifested by drawing such light particles as bits of paper, feathers, etc., to itself. It has also been seen that these light particles only remain attached to the sealing-wax for a short time, after which they are thrown off. This repulsive action follows as a consequence of the light particles being charged in a manner similar to the surface of the sealing-wax, when, as like conditions repel like, the similarly charged

particles are repelled. It has been found that the dried pith of plants and trees may be attracted or repelled in like manner, and, as this material can be easily fashioned into little balls, it has been selected for the purpose of making a delicate indicator of static electricity. As the pith of young elder shoots, when dry, has a larger diameter than that of other English trees, it is the material usually selected for the purpose of making pith balls. A spherical shape is selected, because rounded surfaces do not so readily part with their charge of electricity as angles and sharp points. Pith may be easily carved to any shape with a sharp razor. The pith balls must be suspended by single filaments of cocoon silk to insulated supports of glass or of ebonite, to prevent rapid dissipation of electricity, silk and glass being bad conductors. The support of an electroscope may be a curved piece of wire, bent to the form of a hook at one end, and cemented at the other end into a glass tube to form a pillar, the lower end of which is cemented into a foot or stand of polished hardwood, as shown at Fig. 84, p. 131. A very easy and most inexpensive method of making these instruments is given by Mr. Bottone in his book on "Electrical Instrument Making."[1] Pith-ball electroscopes are made in three forms. 1. A support with one pith ball only suspended to the insulated hook. 2. A support with two pith balls suspended side by side, or two parallel supports with two pith balls suspended to them. 3. Two pith balls balanced on the ends of a straw and

[1] Published by Whittaker & Co., at 3*s*.

secured to a tiny glass cup turning on a glass pivot. Directions for making these are given in the book above mentioned.

2. *Gold-Leaf Electroscopes.* Gold leaf is the thin material used by sign-painters and book-binders to gild letters, and is sold in books for this purpose. It is so light and fragile as to be easily blown away by a light puff of air, or torn by a stronger blast, and is therefore

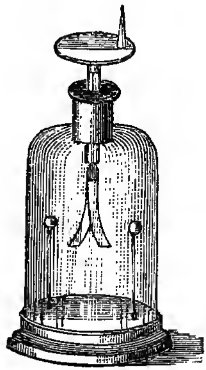


Fig. 81. Gold-Leaf Electroscope.

kept between the leaves of books. This light material will readily indicate the faintest trace of electricity, if suitably disposed and shielded from atmospheric influences. If two thin strips of gold leaf are suspended inside a bottle from its stopper, and a substance charged with electricity is brought near the stopper, the leaves will become charged and will then repel each other. A wide-mouthed thin glass bottle or jar, 3 inches in

diameter, should be selected and fitted with a paraffined hardwood bung through which passes a brass rod terminating at the lower end by a clip for holding the gold-leaf strips and at the other end by a brass knob, a sharp point, or a brass disc. Two strips of tinfoil should be pasted inside the jar from top to bottom, or two brass pillars, terminating in knobs, be fixed in the stand at the bottom, and the jar should stand in a metal tray to facilitate an escape of the electric charge. When the leaves diverge wide enough to touch the tinfoil strips or the brass pillars, they part with their charge. A full illustrated description of this instrument, together with concise instructions for making it from homely materials, is given in Mr. Bottone's book, "Electrical Instrument Making," pp. 14–20.

3. *Coulomb's Torsion Balance.* The electroscopes previously described can only be regarded as indicators of the presence of electricity in a substance. They do not show the strength of electric force. With Coulomb's Torsion Balance, Fig. 82, we can accurately measure the strength of magnetic and electric force, and demonstrate the laws of electric attraction and repulsion. By the aid of this instrument we can easily prove that electric attractions and repulsions are "inversely as the squares of the distances, and directly as the charges."

The construction of this instrument is based on the well-known fact that when a wire is twisted, it offers a resistance to the strain, and returns to its normal condition when the twisting or lateral strain is taken off, if this has not been excessive, so as to give a per-

manent twist to the wire. The form of this instrument is shown at Fig. 82, from which it will be seen that it consists of a glass case enclosing a pointer suspended by a wire from the top of a central glass tube, and another wire (with metal balls at both ends) near the side of the case. The pointer is a slender rod of shellac, carrying at one end a small ball of brass or of copper,

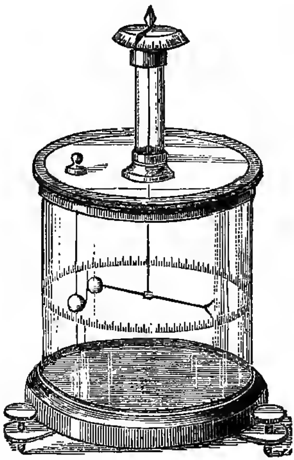


Fig. 82. Coulomb's Torsion Balance.

and nicely balanced in a stirrup at the end of a short length of No. 40 German-silver wire. The upper end of this wire is soldered to a brass rod terminating in a brass ball with an index pointer, and turning freely in a piece of brass tube cemented into the cover of the glass tube. The side of the case is graduated with

marks on the glass, as shown in the figure, or a card-board disc graduated in 360 divisions to the circle is fastened to the base of the instrument under the pointer. If the instrument is to be used for magnetic experiments, the light shellac rod is replaced by a light steel magnet. The price of such an instrument, as given in Messrs. King, Mendham & Co.'s list, is from £3 15*s.* to £5 5*s.* Students desirous of making their own balance from homely materials at a low cost, will find full illustrated instructions in Mr. Bottone's book, "Electrical Instrument Making," pp. 20–23.

Fig. 83. Henley's Pith-Ball Quadrant.

Among many other forms of electroscopes, I may mention Volta's Condensing Electroscope, described and illustrated in "Ganot's Physics," § 769; Henley's Pith-ball Quadrant, illustrated at Fig. 83, and sold for 3*s.* 6*d.*; Cotterell's Electroscope, price 4*s.* 6*d.*, and Lever's Paper Disc Electroscope, price 10*s.* 6*d.* There are also several other forms of electrometers besides Coulomb's Torsion Balance, among the most important being Sir Wm. Thomson's Electrometer, and his absolute Electro-

meter, Lane's Leyden Jar Electrometer, and Harris' Unit Jar Electrometer, all of which are illustrated and described in "Ganot's Physics," § 767 to § 771.

§ 40. **Experiments with Electroscopes.** Several interesting experiments may be performed with electroscopes.

1. Rub a stick of sealing-wax with a piece of flannel, a piece of cloth, or a coat-sleeve, and present it to a pith-ball electroscope. The pith ball will at first be at-

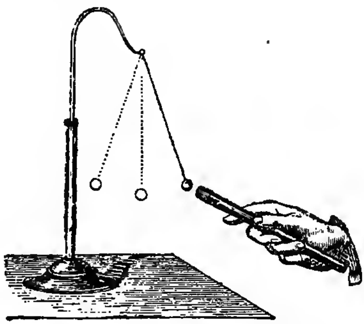


Fig. 84. Pith-Ball Electroscope and Excited Rod of Sealing-Wax.

tracted to the sealing-wax, when it will become charged, and will then be at once repelled, as shown in Fig. 84. Hold the opposite end of the sealing-wax to the pith ball. No effects are observable. The unexcited end is neutral. Reasoning from an analogy between this substance and a piece of magnetized steel, the opposite end should show a reverse electric direction to that which attracted the pith ball. The difference in behaviour is caused by the bad conducting property of the seal-

ing-wax as compared with that of steel. Only the rubbed end of the sealing-wax is electrified. The experiment may be repeated on the gold-leaf electroscope.

2. Procure a glass rod of any length and size, but preferentially, for convenience in handling, from 5 to 6 inches in length, and $\frac{1}{2}$ to $\frac{3}{4}$-inch in diameter. Rub this with a piece of silk, and present it to the pith ball. The ball will be attracted at first, and then repelled, much the same as when presented to electrified sealing-wax. But, now, rub the rod of sealing-wax as well as the glass rod, and present them alternately to the pith ball. The repellent action of one will be reversed by the attractive action of the other. That is to say, whilst the pith ball appears to swing away from the excited glass rod, it will be attracted to the excited sealing-wax. This shows that the directive motion of the excited particles of one substance is not the same in both, one tending to move in one direction, whilst that in the other is opposite. This experiment led Dufay to observe that there were two kinds of electricities, to which he gave the names "*resinous*," when obtained from resinous substances, such as sealing-wax, shellac, resin, etc.; and "*vitreous*," when obtained from vitreous substances, such as glass. Franklin supposed that rubbing the substances with silk, etc., developed in them a kind of fluid, and this became either positively or negatively electrified, the rubbing process either adding to or taking from the fluid some of its properties. This theory acquired apparent support from the fact that

glass behaves differently when rubbed with a catskin than when rubbed with silk. Symmer assumed that all substances contained bound electricity in the form of two fluids united together. By rubbing the substances, these two fluids were separated, one into negative, the other into positive electricity. It need scarcely be said that the fluid theories of these respected investigators, are no longer held by electricians of repute, as modern research has failed to discover any trace of a fluid. The terms "vitreous" and "resinous," as applied to electric action by Dufay, have long since fallen into disuse; but the terms "positive" and "negative," invented by Franklin, are still retained for the sake of convenience to describe two opposite conditions of polarized molecular matter, "positive" representing the condition assumed by vitreous substances when excited, and "negative" representing the condition of the molecules in resinous substances. For still further convenience, by way of abbreviation, the sign (+) has been given to positive conditions, and the sign (—) is given to negative conditions.

3. Procure a rod of shellac, and make for one end of it a tiny cap of flannel provided with a thread of silk. Fit the cap on one end of the shellac rod, and rub it around the rod a few times, then withdraw the cap by the silken thread, and hold it to a pith-ball pendulum. The ball will be repelled, thus showing that it is positively electrified; and, if the shellac rod is presented to a pith ball, it will be attracted, thus proving that both conditions exist, one in the rubber, and the other in the

rubbed substance. A rod of sealing-wax may be used in this experiment instead of a shellac rod, if desired. The experiment should also be tried on the gold-leaf electroscope.

4. Procure several specimens of the following substances, and arrange them in the order given below:—

1. Catskin.	6. Cotton.	11. Sealing-Wax.
2. Flannel.	7. Silk.	12. Resin.
3. Ivory.	8. Wood.	13. Sulphur.
4. Rock Crystal.	9. Copper.	14. Gutta-Percha.
5. Glass.	10. India-Rubber.	15. Gun-Cotton.

The wood (No. 8) must be dry. Other metals beside copper (No. 9) may be employed. Ebonite may be used instead of or with india-rubber. Shellac may be used instead of or with sealing-wax. Vulcanite may be used instead of or with gutta-percha. Gun-paper will be a convenient substitute for gun-cotton. A piece of leather may be added to the list, and a blade of copper, or of brass set in a handle of ebonite, will be a useful accessory.

Rub the catskin and flannel together, then present them both to separate electric pendulums. One will attract the pith ball, whilst the other will repel it. Next rub the piece of ivory with the flannel, and present both to the pith balls. It will be found that the flannel is oppositely excited to its former condition when rubbed with the catskin, and oppositely to the condition of the ivory. On repeating the experiment with all the rest of these substances in order, it will be seen that each

becomes positively excited when rubbed with any of the substances following it in the list, but they are negatively excited by rubbing with those which precede it. On rubbing the naked dry hand with silk or any of the substances preceding it, they become positively excited; but if any of the substances lower down in the list be rubbed with the hand, they will become negatively excited. If ebonite, vulcanite, or gun-paper be rubbed with leather smeared with electric amalgam, they will become positively excited, although their general condition is negative when rubbed with other substances. If two pieces of silk are rubbed together across the grain, one will become positively, and the other, negatively excited. If two pieces of metal, or of wood, or of any other substance, are rubbed together, the piece which is most highly polished will become positively excited, whilst the rough specimen will be negatively excited. A similar effect will follow if the substances are of different temperatures. If a piece of cork and a piece of india-rubber be pressed together, the cork will become positively and the rubber negatively excited. If a piece of metal be rubbed with any other substance, the electricity will escape by the hand and body almost as rapidly as it is formed, because all metals are good conductors of electricity; but, if the piece of metal be held in an insulating handle of ebonite, glass, or ivory, so as to prevent rapid dissipation of the charge, its electrical properties may be investigated. An electric condition may be imparted to the brass knob of a gold-leaf electroscope by flapping it with a piece of catskin, fur,

flannel, or silk, and this condition will be observed by divergence of the leaves.

5. With the gold-leaf electroscope furnished with a metal disc instead of a knob on top, another series of experiments may be performed. Take a piece of sealing-wax and a rod of glass, and rub both with a silk handkerchief. On presenting the excited sealing-wax to the disc, the leaves of the electroscope will diverge, but they will approach each other again when the glass rod is presented, thus showing that two different conditions exist in the two materials. A similar result will follow from the presentation of the electrified substances previously mentioned. Powder a little dry brimstone in a dry porcelain mortar, and let the powder fall on the disc of the electroscope. The leaves will be repelled. Place a little powdered chalk in the nozzle of a bellows, and blow it smartly on the disc. This also will generate enough electricity to cause divergence of the leaves. Comb a bunch of horse-hair or other dry hair, and present it to the disc. Take a strip of black ribbon and a strip of white ribbon, place them together, and draw them smartly between the fingers, then present them to the disc. If this is done in the dark, a spark will pass as the ribbons separate. Rub a sheet of dry brown paper with a piece of india-rubber, then bring this carefully and gradually near the disc. The leaves will be powerfully repelled, and may be ruptured if brought too near. If the experiment is performed in a darkened room, flashes of light will be given off from the paper as it is being rubbed. Freshly ground coffee,

freshly cut chips of wood, and freshly torn bombazine, will all excite the leaves of the electroscope. Rub a silk glove on the hand, then quickly take it off and present it to the electroscope. On touching the disc with the finger when the leaves diverge, they will at once collapse, because they give up their positive charge to the hand.

Stand a boy on an insulating stool, Fig. 85, or on a board resting on four inverted glass tumblers, and let him place the fingers of one hand lightly on the brass disc or knob of the electroscope. No effect will be

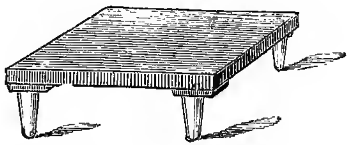


Fig. 85. Insulating Stool.

observed until he is flogged with a silk handkerchief, a piece of fur, or a catskin, when the leaves will diverge and show that electricity has been generated in his coat and conducted to the electroscope.

§ 41. **The Electrophorus.** Although (as shown in § 38) charges of static electricity can be given to simple substances, such as glass, wax, resin, shellac, etc., by merely rubbing them with silk or with wool, the charge given to each is very small, because their capacity for charge is also small. To obtain larger charges of electricity we must have recourse to some apparatus for its production. One of the most simple and least expensive

generators of static electricity, is the electrophorus, an instrument invented by Volta, and shown in one of its forms at Fig. 86. It consists of a cake of resin, or a cake of a mixture of beeswax, resin, and shellac run into a circular shallow tin dish or tray having a diameter of from 12 inches upward, and a thickness of from 1 to 2 inches according to the diameter. Smaller discs may be used if desired, down as low as 5 inches in diameter; but the effects from small discs are not so good as those from larger discs. A cake of brimstone in a metal tray, or a disc of ebonite, or of papyroxyline, cemented to a

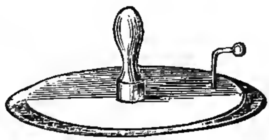


Fig. 86. Electrophorus.

metal disc, will serve equally as well as a cake of resin; in fact, the latter substance (which is made of millboard immersed for a few seconds in a mixture of nitric and sulphuric acids, and then washed in an abundance of water) is deemed one of the best for this purpose, as it is practically indestructible, and yields good results. A metal disc, smaller than the lower one, or a wooden disc coated with tinfoil, either of which must be furnished with an insulating handle of glass, ebonite, or baked wood, must now be provided, and furnished with a metal contact hook and ball, as shown in Fig. 86. Detailed illustrated instructions for making a cheap

form of this instrument are given in "Electrical Instrument Making," pp. 23–28. Small instruments, from 5 to 10 inches in diameter, are sold by dealers in electrical instruments, at a cost of about 1*s.* per inch. Larger ones may be made to order, or may be made by the student himself. I advise the latter course, as by doing this, much practical amusement may be obtained.

§ 42. **How to Use an Electrophorus.** Slightly different methods of using this generator of electricity, are adopted to suit slight modifications in its form, but all obey the general electrical law that there can be no electrical action apart from a closed circuit of conductors. Let us take the most simple form of electrophorus first; viz., one composed of a cake of resin or of sulphur in a wooden tray, coated and lined with tinfoil, and furnished with a wooden cover coated with tinfoil. An electrified condition is imparted to the cake of resin by briskly flapping it with a piece of silk or a piece of fur, or, better still, a catskin. If the instrument is insulated by placing it on a piece of ebonite or a piece of glass, and we touch its surface with an insulated proof plane, no charge whatever will be communicated to the plane. But if the metal coating of the electrophorus is not insulated, and the electric circuit is completed by touching the plane with the finger before removing it from the cake of resin, it will be found to be charged with electricity. To use this instrument properly, its outer coat must be connected to its cover, and, in best-made instruments, this is provided by means of a metal hook on the cover, terminating in a ball, which is made to touch the

outer coating or the metal tray before the cover is lifted. The tray is also provided with a metal hook, to which is attached a piece of clock-chain allowed to dangle on the floor. If no such provision is made in an electrophorus, the surface must first be briskly flapped with silk or with fur, the cover then put on and touched with one finger, then raised from the cake, when it will be found to have taken a charge from the excited resin. This may be discharged into a Leyden jar, and the process repeated again and again until the jar has been charged, or the charge of electricity exhausted, without having to flap the cake every time the cover has been removed. If, on lifting the cover from the cake with one hand, the knuckle of a finger on the other hand is presented to the rim, a sharp spark will pass from the cover to the finger. If a piece of clock-chain is attached to the metal tray, and the end of the chain is held in one hand, whilst the face of the instrument is flapped with a piece of catskin, fur, or silk held in the other, a much stronger charge will be imparted than when the chain is allowed to dangle on the floor. Here again is shown the workings of the law of electric circuit. When the electrophorus is flapped on an insulating stand, no charge whatever can be discovered on its surface by a proof plane; if the instrument is placed on an ordinary table, the circuit is completed by imperfect conductors, namely, the table legs, the floor, and the body of the operator; but when the outer coating is connected by a chain with the floor, the circuit is improved, and a still further improvement is effected by providing an

easier circuit, as when the chain is held in the operator's hand.

An electrophorus should be kept in a dry place, free from dust, when not in use. It must be carefully wiped and freed from dust before using it, and improved effects are obtained when the instrument is slightly warmed before it is used.

§ 43. **Experiments with the Electrophorus.** With a good electrophorus, the range of experiments is still further extended. We can cause attraction and

Fig. 87. Proof Plane.

repulsion of electroscopes by drawing off the charge with a proof plane, or we can measure the tension of electric force by means of a Coulomb torsion balance, or we can charge Leyden jars and condensers, and perform many of the experiments in which high-tension sudden discharges are employed. The proof plane (Fig. 87) is merely a small electrophorus cover, or tiny disc of sheet metal attached to an insulating rod of glass, of shellac, or of ebonite. It is used in the same way as the cover of the electrophorus, to draw off small charges

from this instrument, or to convey such small charges from any other instrument to an electroscope. In some forms, a brass ball is used instead of a brass disc.

1. *Charged Hollow Sphere.* Procure a hollow copper ball or sphere from 4 to 5 inches in diameter, similar to those in use for the ball taps of water cisterns, having an aperture of 1 inch in diameter on one side, and a connecting socket of brass on the opposite side. Cement

Fig. 88. Insulated Hollow Sphere.

a glass rod into this socket, and mount the sphere on the top of this in a suitable stand of polished mahogany (see Fig. 88). Place this insulated sphere under a projecting arm of glass—a horizontal glass rod, for instance—from which depends a piece of brass clock-chain passing into the interior of the sphere through the hole in its side, and touching the inside bottom. Charge this sphere with electricity from the electrophorus by hold-

ing the charged cover to the brass chain several times, then withdraw the chain, and test the interior of the sphere for electric charge by introducing a proof plane through the opening, withdrawing it, and presenting it to one of the electroscopes. No charge whatever can be discovered on the inside of the sphere, although we are sure it has been charged. Touch the outside of the sphere with the proof plane, and again present it to the electroscope. Evidence of a charge will be at once

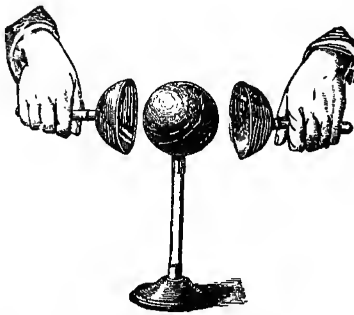


Fig. 89. Biot's Experiment with Charged Hemispheres.

obtained, thus proving that static electric charges pass to the outsides of charged substances.

2. *Biot's Experiment.* This may be further proved by taking another metal sphere, dividing it into two equal parts attached to insulating handles, and holding the two halves so as to envelop the insulated sphere used in the last experiment. On charging the interior of the sphere, and holding the two hemispheres over it for a moment, then separating them, they will both be found

to have received an electric charge, whilst the sphere itself will be quite neutral, the charge having passed into the two enveloping hemispheres.

3. *Faraday's Butterfly Net.* This law may be further illustrated by means of an experiment devised by Faraday. Attach a conical gauze net or butterfly net to a metal ring, and mount this on a glass rod or insulating stand (see Fig. 90), then tie a silk thread to the

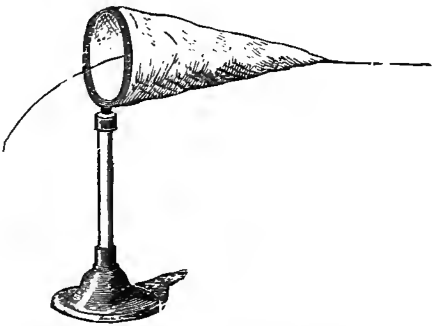


Fig. 90. Insulated Butterfly Net.

point of the cone, and turn the net so as to have the silk thread inside, then charge it with electricity. On testing the outside of the net by holding a proof plane to it, and presenting the proof plane to an electroscope, the outside of the net will be found to be charged with electricity, whilst the inside is neutral. But if the cone is turned inside-out by pulling the silken string, the charge will pass from one side to the other, and still be found outside. This may be repeated as long as the

net remains charged. A bird-cage may be electrified in like manner without affecting an electroscope placed inside, and may be made to receive a sufficiently strong charge to give forth sparks without affecting a bird occupying the cage. If, however, a cylinder of metal be placed in a cylinder of ebonite, and this enclosed in an outer cylinder of metal, the inner cylinder may be charged without giving up its charge to the outer cylinder.

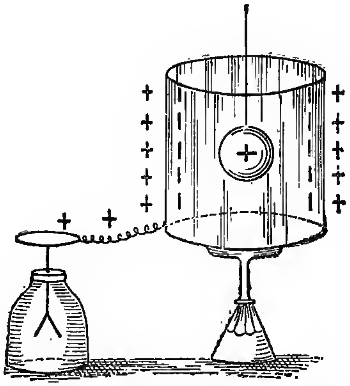


Fig. 91. Insulated Metal Cup and Electroscope.

4. *Charged Metal Cups.* That an electric charge will pass through supposed insulating substances, may be illustrated by the following experiment. Procure a metal cup or mug, and place it on an insulating support, or on a glass tumbler or goblet, as shown at Fig. 91. Solder a thin copper wire to the outside of the metal mug, and connect the other end of this wire to the metal

knob of a gold-leaf electroscope. Fix a brass ball to a shellac rod or to a thread of silk, and positively charge it from the cover of an electrophorus. On introducing

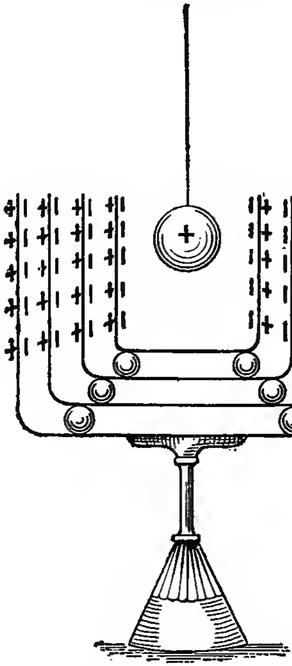


Fig. 92. Involved Insulated Metal Cups.

the electrified ball into the metal vessel, the leaves of the electroscope will be seen to diverge, thus showing that the charge has passed from the ball to the metal cylinder through air, and has positively charged the outside. This may be proved by holding the ball to an electro-

scope, and testing the interior of the metal vessel with a proof plane. If now we procure some three or four such metal vessels, each larger than the other, and insulate them from each other by cakes of shellac, as shown in Fig. 92, connecting the outer vessel to an electroscope, as before, the same result will be obtained, and, if the inside vessel is connected to earth by touching it with a finger, the leaves of the electroscope will immediately collapse.

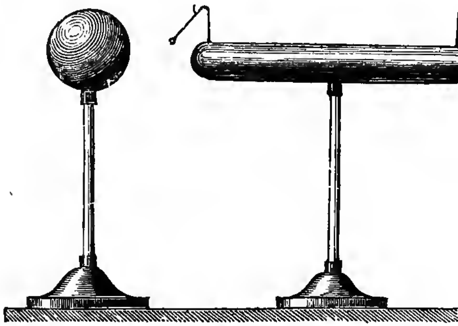


Fig. 93. Insulated Ball and Cylinder coated with Tinfoil.

5. Procure a piece of well-seasoned walnut, mahogany, or other hard wood capable of furnishing a cylinder 10 inches in length by 3 inches in diameter, with rounded ends. Turn this quite smooth, and smoothly coat it with tinfoil. Half-way along on one side, bore a socket with a centre-bit, to fit on a glass rod destined to form an insulating handle or the pillar of an insulating support when the other end is cemented into a suitable foot or stand. On the opposite side, drill five $\frac{1}{16}$-inch holes, to

the depth of $\frac{1}{4}$-inch, one in the centre, one at each end, $\frac{1}{2}$-inch in from the rounded end, and two midway between the centre and ends. A polished brass cylinder, similarly shaped and mounted, may be used instead, if desired. The form is shown in Fig. 93, and the prices are respectively 4*s*. and 13*s*. 6*d*. The first experiment with this may be tried on a charged electrophorus with-

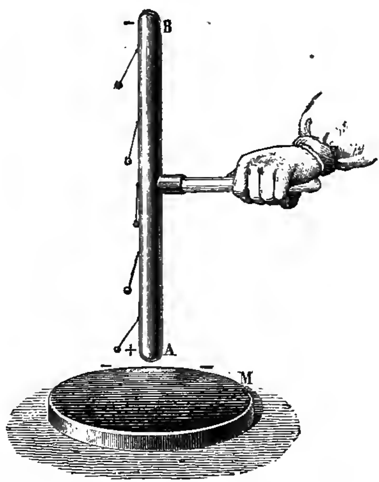


Fig. 94. Experiment with Insulated Cylinder and Electrophorus.

out a cover. Get five pith balls, and glue them to pieces of linen thread 3 inches in length, then attach these threads to wooden pegs fitting in the five small holes on the cylinder. Holding the insulating support in one hand, and bringing the cylinder in a vertical position, with its lower end over the electrophorus, as shown in

Fig. 94, the lower pith ball will be seen to diverge at a wide angle, the next at a more acute angle; the middle ball will lie close to the cylinder, unaffected by the charge; the next will diverge slightly, and the top ball still wider; thus showing that the whole cylinder is inductively charged with electricity, and the extremities, as well as the central portion, exhibit all the peculiarities of a charged steel magnet with opposite poles and a neutral space between.

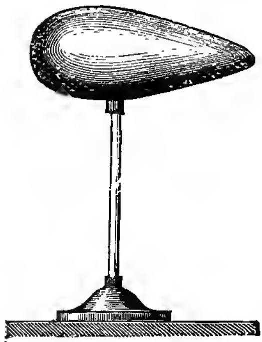


Fig. 95. Insulated Cone coated with Tinfoil.

In the next experiment this property of static electric charge is even more pronounced and clearly illustrated. It is performed with two spherical condensers placed at short distances from each end of the cylinder used in the first experiment. These condensers may be wooden balls some 4 or 5 inches in diameter, mounted on insulating pillars, and coated smoothly with tinfoil, or they may be made of metal, and similarly mounted (see

Fig. 93). These spherical condensers may be placed at a distance of 2 inches from the end of the cylindrical condenser, and two pith balls suspended by linen threads from hooked wires should be placed in position in the two end holes in the cylinder. On charging one of the spheres with electricity from the electrophorus, both pith balls will be seen to diverge from the stems of their supports, and, on testing the surface of the second sphere with a proof plane on the side farthest from the charged sphere, it will be found to be positively charged. The cylinder will also be found to be negatively charged at the end nearest the charged sphere, and positively charged at the opposite end. This may be proved by holding an excited stick of sealing-wax to the pith balls alternately, when that nearest the charged sphere will be repelled by the negative sealing-wax, whilst the other will be attracted to it. A further proof is afforded by testing them with a glass rod positively excited by rubbing it with silk. The condition of the cylinder will therefore be seen to be analogous to that of a permanent magnet having opposite polar extremities and a neutral centre. It also obeys analogous laws of induction, as it induces an electric condition in contiguous substances susceptible to the influence of electrical excitation.

6. Procure a cone of smooth wood, shaped as shown at Fig. 95; mount this on an insulated stand, and coat it with tinfoil. Charge this as the cylinder was charged, then test the density of the charge at various parts of the cone, by means of a proof plane or an electroscope. The strongest effects will be obtained from the point of

the cone, and the least effects from the largest and most bulky part. This shows the tendency of electric charge to concentrate itself towards points and edges, much the same as magnetic charges are most strongly observable on the edges of magnets.

§ 44. **Leyden Jars.** The range of experiments with an electrophorus may be largely extended by using it to charge Leyden jars, and then using these in performing experiments. A Leyden jar is a condenser formed of a

Fig. 96. Leyden Jar.

glass jar or wide-mouthed glass bottle, coated inside and outside with tinfoil up to within an inch or so of the top. The mouth of the jar is stoppered with a bung of polished hardwood, through which passes a brass rod terminating on the top in a brass ball, and having a piece of brass chain depending from its inner end, or else an extension to touch the bottom of the jar. A Leyden jar is shown at Fig. 96, and its construction is clearly described and illustrated in "Electrical Instrument Making," pp. 71–75.

When the jar is intended to be charged from an electrical machine, the brass rod is made longer than usual, and is bent in the form of a shepherd's crook, for convenience in hanging the instrument on the prime conductor of the machine. Two or more Leyden jars placed in a wooden tray lined with tinfoil, and connected together on top (as shown at Fig. 97), constitutes an electric battery, which is capable of receiving a higher

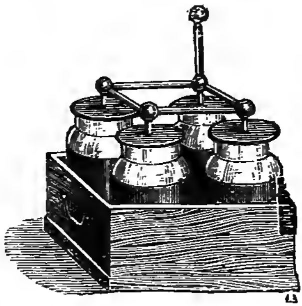


Fig. 97. Battery of Leyden Jars.

charge than a single jar. When a jar is coated inside and out with diamond-shaped pieces of tinfoil instead of a continuous sheet (as shown at Fig. 98), the jar is named a "spotted jar," and forms the means of a very pretty experiment, in which the charge and discharge breaks across the patches of tinfoil in the form of vivid sparks. Messrs. King, Mendham & Co. make a special form, which they name a High Insulation Leyden Jar. In the construction of this jar, advantage is taken of the known tendency to electrical leakage through the

wooden cover of an ordinary jar, to dispense with a cover altogether, and thus attain a higher state of insulation. This form is shown at Fig. 99. Leyden jars without covers are more easily made than those with covers. Open glass jars, such as those used by confectioners, should be selected. They are easily coated inside and out with tinfoil. The brass stem of the jar may be fixed into a cross-piece of sheet lead or to a

Fig. 98.
Spotted Leyden Jar.

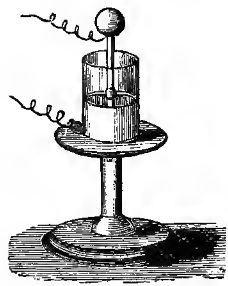


Fig. 99.
High Insulation Leyden Jar.

cone of lead, and this may be secured to the bottom of the jar by a touch, here and there, of thick shellac varnish, or glue, or china cement.

Fig. 100 shows a form of Leyden jar with movable parts, destined for use in experiments to demonstrate whether the static charge is retained in the glass or in its coatings of tinfoil. It consists of a thin glass tumbler, and a tin cup made to fit the outside of the tumbler, and a cone of wood coated with tinfoil to fit the inside of the tumbler, this cone being furnished with

the usual brass stem and knob in use with ordinary Leyden jars. The prices of ordinary Leyden jars run from 2*s*. for a ½-pint jar, measuring 4 in. × 2 in., up to 8*s*. 6*d*. for a 2-quart jar, measuring 10 in. × 5 in. Batteries of jars cost 18*s*. 6*d*. for 4 jars of pint size, up

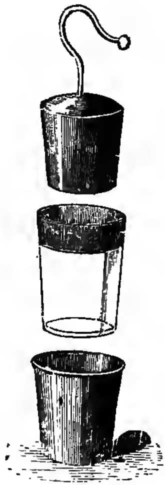


Fig. 100. Leyden Jar with Movable Coatings.

to £4 10*s*. 6*d*. for batteries of 9 jars of 2-quart size. Diamond spotted or spangled jars cost from 6*s*. to 8*s*. 6*d*., according to size. Jars with movable coatings, cost from 6*s*. 6*d*. to 8*s*. 6*d*. each. "High Insulation" jars, cost 3*s*. 6*d*. and 4*s*. 6*d*. each.

§ 45. **Experiments with Leyden Jars.** With a charged Leyden jar, a large variety of experiments

may be performed, and with a battery of such jars the scope of the experiments may be extended. Very many of the experiments performable with the spark from an induction coil, detailed in §§ 26 to 28, may also be performed with the spark obtained from a charged Leyden jar. The most prominent and interesting of these are:—1. Deflagration of Wire. 2. Deflagration of Metal Filings. 3. Deflagration of Metal Foil. 4. Ignition experiments. 5. Lighting Gas. 6. Exploding Fuses, and Firing Electric Pistols or Mortars. Besides these, the following experiments may also be performed.

1. *Charging Leyden Jars.* Leyden jars, as first seen by the amateur electrician, student of electricity, and experimenter in scientific subjects, appear to be an ingenious contrivance for bottling electricity under pressure. It would seem as if an electric fluid was injected in small quantities from an electric machine into a jar, and held there under pressure, much the same as mineral waters, ginger beer, lemonade, etc., are held under pressure in glass bottles. Such, however, is not the case. Whatever electricity may be, it is not a fluid in itself, nor can it be said to be held in a Leyden jar under pressure, since the tension or pressure is the same in jars of all sizes, and no method of pumping, or other method of compressing fluids, has yet been found to increase the tension of an electric charge. The volume or quantity of the charge increases with the size of jar, but the tension remains the same. The condition of a charged Leyden jar is much the same as that of a magnetized steel bar. One of its

coatings is positively and the other negatively electrified. All its parts are made up of polarized molecules of matter, much the same as those of a bar of magnetized steel. Its capacity for charge is limited by the quality of the material employed in its construction, and the extent of its polarizable surface. It obeys, however, the laws of electric circuit, and therefore cannot be fully charged if placed on an insulating support. There must be a complete chain of conductors between its outer and inner coating, so as to form a complete circuit, although, to ensure success, some of these must be such bad conductors as glass, and the human body. To demonstrate this, place a Leyden jar on an insulating support near the prime conductor of an electric machine. When within striking distance of the machine, one or two sparks will be seen to pass from the conductor to the knob of the jar, and the inner coating will receive a faint charge, but the outer coating will be unaffected. Now grasp the jar with one hand, and thus provide a circuit of better conductors than glass, or connect the outer coating to earth by means of a piece of sheet metal and a piece of clock-chain, and again attempt to charge the jar. A series of sparks will now pass to the jar, and it will be fully charged inside and outside. It is therefore usual to place the jar in connection with the earth, or to hold it in one hand whilst being charged. The jar may then be charged by holding it to the conductor of a machine, or from an electrophorus, or by being placed in connection with an induction coil, as directed in § 30, p. 91.

If we wish to have at our command a large quantity or volume of electricity, we must employ, either large jars of large capacity, or connect several jars together

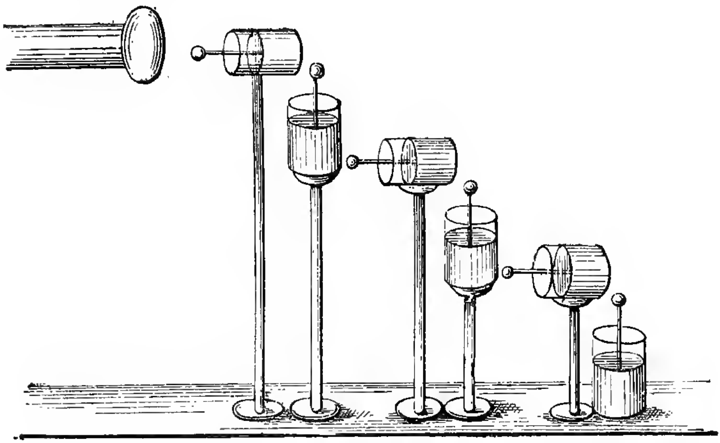


Fig. 101.

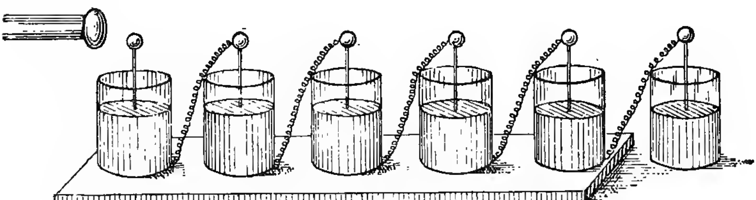


Fig. 102. Methods of Charging Leyden Jars in Cascade.

for quantity, just the same as in a voltaic battery, that is by connecting their positive poles (knobs) together, and their negative poles (outer coatings) all together

(as shown at Fig. 97), the latter being easily achieved by placing the jars in a tray lined with tinfoil. When we wish to have the charge at a higher tension than can be obtained from one jar, we must connect a number of jars together in series, just the same as the cells of a voltaic battery are connected,—that is, connect the knob of one jar to the outer coating of the next, and the knob of this to the next, and so on through the series, each jar, except the last in the series, being placed on an insulating support, as shown at Fig. 101.

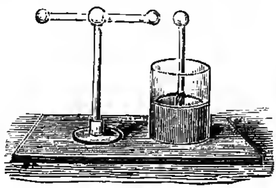


Fig. 103. Lane's Electrometer.

The whole series may then be charged from one source at the same time, and this method of charging has been named charging in cascade. Other methods of charging Leyden jars in cascade, are shown in the annexed figures, taken from Mr. Bottone's book on Electricity and Magnetism.

The capacity of a jar for electric charge depends upon the extent of its coated surface, and the thickness of the glass employed in its construction. Thick glass offers too much resistance to the charge. According to Wheatstone, the quantity of electricity which can be got into a jar, is proportional to the extent

of its coated surface, and inversely proportional to the square of the thickness of the glass. The limit of charge may be determined by means of a Henley's quadrant electrometer (Fig. 83, p. 130), attached to the jar being charged, or a Lane's electrometer (Fig. 103), for determining the striking power of the charge through air space, or a Harris' unit phial (Fig. 104), placed in circuit with the jar being charged. The Henley quadrant is merely a pith ball attached to

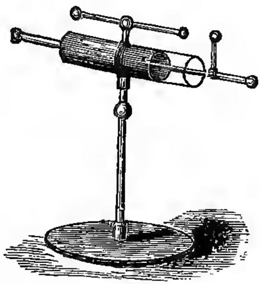


Fig. 104. Harris' Unit Phial Electrometer.

the end of a shellac or whalebone arm, and pivoted to the upper part of a graduated quadrant. The pith ball rises as the charge increases in the jar. This instrument is sold for 3*s*. 6*d*. Lane's electrometer is merely a Leyden jar placed near a metal arm, as shown in the figure. The outer coating of the jar being charged, is insulated, and then connected by a wire to the knob of this extra jar, the outer coating of which is connected with the ground. The knobbed arm is then brought close to the knob of the jar, and after-

wards withdrawn to a striking distance from the knob. The quantity of electricity in the charged jar, is determined by the number of sparks passing between Lane's jar and the knob of the metal arm. Lane's instrument, costs from 10*s.* 6*d.* to 15*s.* 6*d.* Harris' unit jar or Leyden phial, is a glass cylinder constructed similar to a Leyden jar, and made to contain a certain or unit quantity of electric charge. When this instrument is placed in circuit with a Leyden jar being charged,

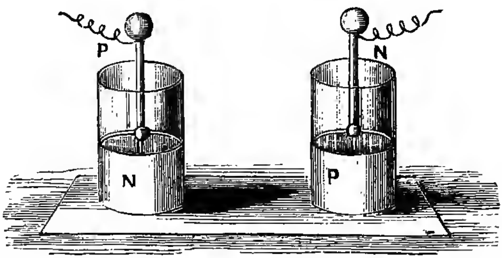


Fig. 105. Leyden Jars on Tinfoiled Base, showing Relative State of Charge.

the unit phial first receives a certain quantity of charge, and then discharges it into the jar. This is repeated until the jar has been deemed to have a sufficient number of unit charges. The price of Harris' instrument is one guinea. Jars are, however, charged in a rough and ready manner by passing sparks into them until no more appear to pass, or by counting the number of sparks, or by counting the number of turns of the electrical machine charging them.

2. *Discharging Leyden Jars.* The electrical condition

of a Leyden jar when charged, is negative on one coating, and positive on the other. As ordinarily charged, the inner coating is positive, and the charge has a high potential or pressure. The outer coating is negative, and is insulated from the inner coating by the glass of the jar. Unless the glass is defective or the jar too highly charged, this insulating medium is quite sufficient to prevent the two coatings being connected in circuit. When, however, a conductor is allowed to touch the knob on top of the jar and the outer coating, the circuit is completed, and the electricity is said to be discharged. If, therefore, we take a half-pint Leyden jar and charge it with electricity, then grasp the jar with one hand, whilst we touch the knob of the jar with the knuckles of the other hand, a spark will pass from the knob of the jar to our knuckles, because the body forms a conductor and completes the circuit of conductors. If the jar stands on an ordinary table, uninsulated from the ground, and its knob is touched in a similar manner, the charge will also take advantage of this closing of the circuit and discharge itself through the body, the table, and the floor of the apartment, all of which are conductors to electric currents of high potential. If the charged jar is placed on an insulating block of glass, or an insulating stand, then touched with the knuckles, only a partial discharge takes place in the form of a faint spark. If now we touch the outer coating, a spark may be obtained from it also, then another may be got from the knob, another from the outer coating, and so on until all the charge has been

withdrawn in small quantities. These experiments may only be performed with small jars. On no account should we attempt to take a charge from a large jar, or a battery of jars, as the sudden shock to the nerves by the passage of a large volume of current at a high tension, is likely to have disagreeable and injurious results.

3. *The Use of Dischargers.* On account of this danger, it becomes necessary to use specially insulated instruments in experiments with Leyden jars, and these

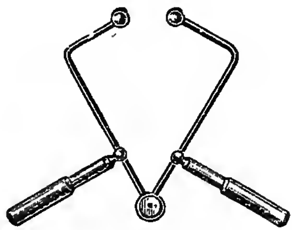


Fig. 106. Discharging Tongs.

instruments are known as dischargers. The most simple form is named a hand discharger, and is simply a pair of wires, terminating in brass balls, fixed to a compass adjustment, and attached to an insulating glass handle. In the next form (Fig. 106), two glass or ebonite handles are provided, and the instrument is named "discharging tongs." To discharge the jar with the hand discharger, first adjust the two arms to a distance apart equal to that between the outer coating of the jar and its knob, then place one ball on the

outer coating, and bring the other gradually to the knob of the jar. When near to it, but not quite touching, a spark will flash from the knob, and this is an evidence of the jar being discharged. On bringing the ball nearer, after the first discharge, a feeble second spark may be obtained. With the discharging tongs, both hands may be employed, and the arms of the instrument adjusted to a nicety whilst approaching them to the knob. Hand dischargers cost 3*s.* 6*d.*, and discharging tongs from 6*s.* to 9*s.*, according to length and finished workmanship; but both may be easily made, by the amateur experimentalist, from a few pieces of wire and glass. Knobs must be used instead of points as terminals to all electro-static instruments, because best effects are obtained from knobs, the spark from a point being small and of a feeble character, and all points and sharp angles draw off electric charge into the air quietly and silently.

Discharging Leyden Jars with Movable Coatings. The discharge of a Leyden jar furnished with movable coatings, as shown at Fig. 100, p. 154, provides means for a very interesting experiment, showing that the electric charge is taken up and retained by the glass of the jar. After the jar has been charged, it must be placed on an insulated table (Fig. 114, p. 169), or on a cake of resin. The inner coating may be removed by placing a glass rod under the hook, and lifting it out of the tumbler. Then the glass vessel is raised, and the metal cup removed and placed on a table, leaving the glass tumbler alone on the insulated table. On testing

both inner and outer coatings with the proof plane, little or no charge will be discovered; but on restoring them to their former positions and then testing them, a sharp discharge may be obtained in the form of a shock or a spark.

When using charged Leyden jars in the form of a battery for large experiments, and also when using condensers (noted further on), we must employ another form of discharger, shown at Fig. 108, and known as

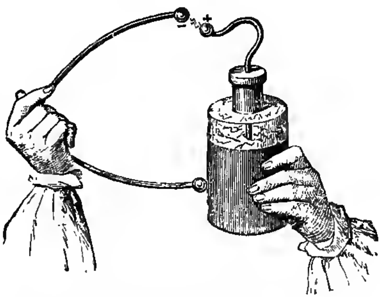


Fig. 107. Discharging a Leyden Jar.

Henley's discharger. This is similar to the instrument in use for discharges from induction coils, in fact one or both may be used for the same purpose by merely substituting knobbed terminals for points, or the reverse as required. A special form of this instrument, furnished with cup and ball joints and a fixed insulated table, as shown in the annexed figure, costs 25*s.* 6*d.* This is a superior and handy combination of Leyden jars and discharger, made by Messrs. King, Mendham & Co. The insulated discharger rods work in a socket

pierced through a brass ball, and this works in a cup. The dischargers can therefore be adjusted to any

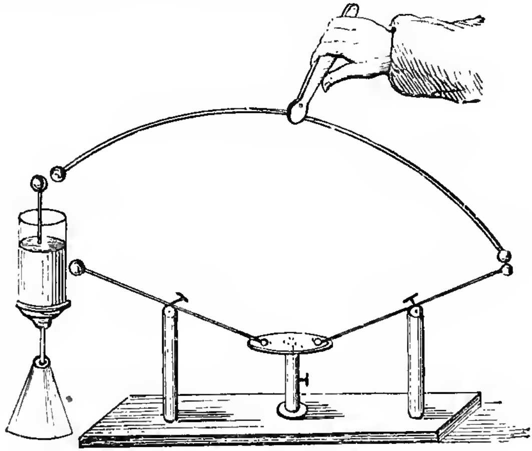


Fig. 108. Discharging Insulated Leyden Jar.

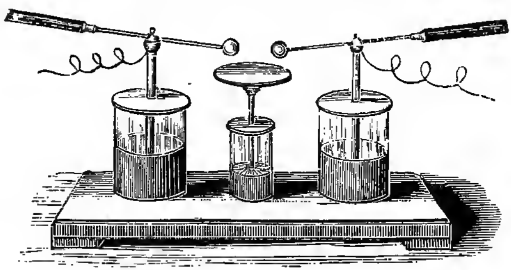


Fig. 109. Henley's Universal Discharger.

distance within their range, and the discharge directed at any angle. The jars may be charged as they stand

or the instrument may be used when connected to an outside source such as a battery of jars or an electric machine, in which case the jars are useful in taking up an extra charge. The central table has its foot embedded in paraffin wax contained in a glass jar, and thus a high insulation is attained. The price of this instrument is £1 5*s.* 6*d.*

A cheap arrangement for this experiment (from Mr. Bottone's new book)[1] is shown at Fig. 108.

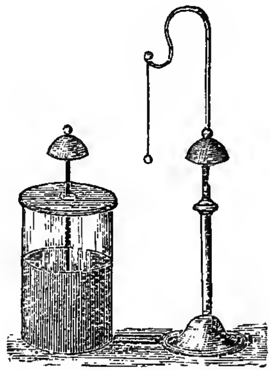


Fig. 110. Electrical Chimes.

4. *Electrical Chimes.* When experimenting with a charged rod of sealing-wax and a pith-ball electroscope, we observed that the pith ball was first attracted to the rod, then repelled as it became charged. This experiment may be repeated with a charged Leyden jar on a

[1] "Electricity and Magnetism," Whittaker & Co., London, price 3*s.* 6*d.*

stand, as shown at Fig. 110, where the jar is shown with a small bell instead of a knob, and another bell mounted on a pillar near it. The projecting arm above this bell, carries a small brass ball suspended to a fibre of cocoon silk. The pillar stands on a strip of tinfoil in contact with the outer coating of the jar. When the jar is charged, its bell will attract the metal ball to itself, which then becomes charged positively, and, as a consequence, will be repelled against the negatively charged bell on the pillar; this in turn will give up a part of its negative charge to the ball and repel it toward the jar. This to-and-fro movement will be repeated until the jar has been slowly discharged.

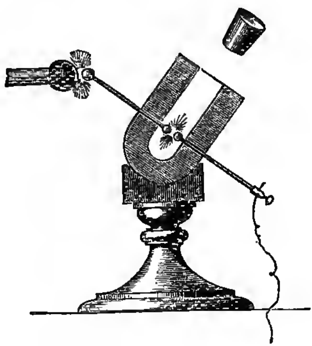


Fig. 111. Electric Mortar.

5. *Electric Mortar or Cannon.* The charge from a battery of Leyden jars may be utilised to fire a fuse, or fire gunpowder. This may be illustrated by means of the following experiment. Procure a heavy block of

hard wood, and turn out (in a lathe) a model of a cannon or a mortar with thick sides and a $\frac{3}{4}$-inch bore. Near the bottom of the bore, insert two brass wires with rounded ends at a fractional distance apart. The outside ends of these wires should terminate in a shepherd's hook and knob, or as shown in the annexed figure (Fig. 111). The cannon or mortar may be charged with equal parts of chloride of antimony and chlorate of potash finely powdered separately, then mixed with a feather. Connect one of the hooked ends by means of a clock-chain with

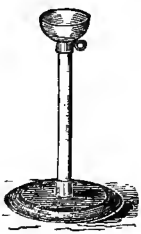


Fig. 112. Insulated Cup.

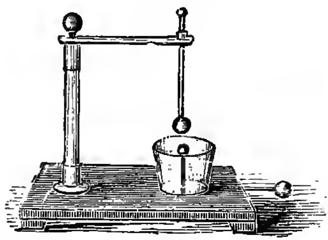


Fig. 113. Glass or Card Piercer.

a metal plate on which the charged jar rests, connect the opposite hooked end by means of a piece of clock-chain to one limb of the discharging tongs, and then discharge the jar by touching the knob in the usual way with the other limb of the tongs. If all has been properly arranged, the charge in the mortar will explode with a loud report. Of course the charge must be small, and reasonable care taken to prevent injurious results from the explosion. A Henley's discharger may be similarly connected to a jar or a battery of jars, and

various substances, such as powder, gun-cotton, lycopodium, etc., as described in the experiments with induction coils, may be inflamed by discharging the jars through them. When it is intended to inflame phosphorus or ether and other inflammable liquids, they are usually held in an insulated cup, such as that shown at Fig. 112, the price of which is 3*s*.

6. *Piercing Cards or Glass.* The apparatus shown at

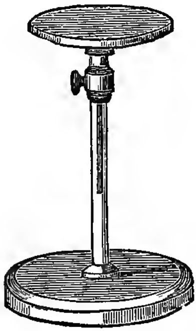


Fig. 114. Insulated Table.

Fig. 113 is intended to facilitate the experiment of piercing a card or a piece of glass by discharging a Leyden jar through a card or glass placed horizontally between the two vertical knobs shown in the figure. The upper knob is adjusted until the best effect is obtained. The price of this apparatus is 9*s*.

7. *Imitation Lightning.* A thunderstorm is caused by an accumulation of electric charge in clouds, which form condensers similar to massive Leyden jars; and

when some of these become positively charged with electricity at a high tension, whilst others are negatively charged, the overbalanced force naturally tends to obtain a balance by a discharge of the higher potential charge into a lower. This discharge sometimes takes place between neighbouring clouds, when these are differently charged. This celestial discharge may be imitated by enveloping the discharger balls of a Henley's discharger with masses of cotton wool to resemble clouds, connecting them in circuit with a battery of Leyden jars, and bringing the clouds gradually toward each other until the discharge takes place between them. The loud crackling noise of the spark will give some idea of the cause of thunder, if we take into consideration the enormous potential of a flash of lightning as compared with that of a spark from a Leyden jar, taking 50,000 volts to represent the tension of an inch spark in air.

Electric discharge always takes place from cloud to earth, or from earth to cloud, over paths or lines of least resistance, or, which means the same, through a chain of best conductors. If, therefore, the line of least resistance lies between such a bad conductor as air and a chain of alternate good and bad conductors such as masses of metal separated by wood or by masonry, the discharge will take place in the latter, but the strain in the bad conducting portion of the chain will be so great as to cause disruption of the chain. This is shown by means of model buildings, named in makers' price lists, "thunder-houses." A model house is made of wooden

blocks loosely kept in place by wire pins, and by metal hinges. A model lightning conductor is fixed to the chimney, but is not carried to earth, *i.e.* to touch the tinfoil strip on which the house rests. The end of this conductor terminates close to the key pin of the whole structure, and this is in connection with some of the other pins which loosely hold the wood blocks together, and finally within striking distance of the tinfoil base. This resembles the worse than useless method of erect-

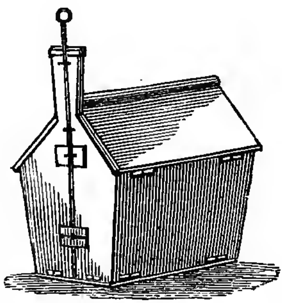


Fig. 115. Thunder-House.

ing lightning conductors adopted by some builders, who connect all the building to the conductor, but fail in bedding the lower end of the rod deeply in damp soil below the level of the foundations of a house. In our lightning rod, the top should have a small brass knob instead of a point. To illustrate the action of lightning on such a building, place the tinfoil base in connection with the outer coating of the Leyden jar and discharge the jar with the tongs through the lightning conductor,

when the charge will leap from the defective rod to the key pin and bring down the whole structure. "Thunder-houses" fitted for the purpose, cost from 5*s.* to 16*s.* 6*d.*, according to fittings, material, and finish. A model of a factory with a high stack, or of a church with tower and steeple, or of an obelisk, or of the mast of a ship suitably jointed to easily fall, and provided with a dis-jointed conductor, may be substituted for an ordinary house, or several such models may be prepared for this

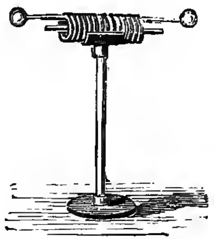


Fig. 116. Static Magnetizer.

purpose. A very striking effect may be produced by having a model ship furnished with a prepared mast, and floated in a metal tray under an insulated thunder cloud, connected to a charged Leyden jar. When the mast of the ship comes within striking distance of the cloud, the circuit is completed, there is a sharp crack and a flash, and the stricken ship is at once dismasted.

By the exercise of a little ingenuity, the explosive effects of the discharge may be combined with the dis-ruptive effects, and some ether fired, or the explosive

mixture previously noted may be exploded in the house or in the ship.

8. *The Static Magnetizer.* Fig. 116 shows a Static Magnetizer for magnetizing a steel rod by the discharge from a Leyden jar. It consists of a helix of copper wire furnished with terminal knobs, mounted on an insulated stand. A hardened steel bar is placed in the helix, and a charged jar is discharged through the helix by means of the discharging tongs in the usual manner. The bar will be found to be magnetized, thus showing that electricity, from whatever source obtained, is the same in character and action.

9. *Fulminating Panes.* Although the jar and bottle form of condenser is in general use for experimental purposes, all the effects obtained from charged jars may also be got from single panes of glass coated with tinfoil on both sides to within one inch of the edges, and mounted on an insulated stand of baked and paraffined wood, as shown in the annexed figures. These panes of glass can be charged much the same as Leyden jars, a bent piece of wire being placed against one side, as shown in Fig. 117, to connect that side with earth. A pane so charged may be discharged with a pair of discharging tongs, as shown in Fig. 118, and the discharge will be accompanied by a smart report, which has given this instrument the name of a fulminating pane. It may also be charged with current from a spark induction coil.

§ 46. **Condensers of Electricity.** All the effects obtained from a Leyden jar, may also be obtained from a

condenser such as that employed in the construction of induction coils, described in "Induction Coils," § 23, and in "Electrical Instrument Making," § 47. Among con-

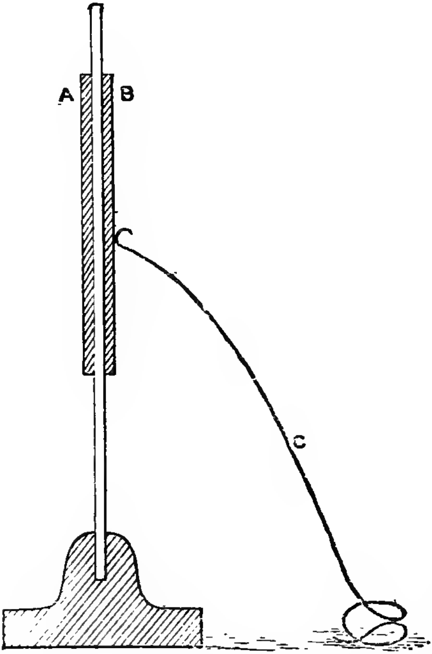


Fig. 117. Section of Fulminating Pane showing Method of Charging it. A. Positive. B. Negative. C. Connecting Wire.

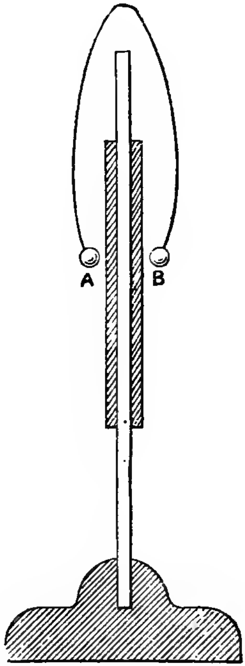


Fig. 118. Discharging Fulminating Pane.

densers, may be mentioned Franklin's Fulminating Pane, which was simply a pane of glass coated on both sides with tinfoil to within 1 inch of its edges, thus forming,

as it were, a Leyden jar flattened out; Fizeau's Condenser, described in the books above mentioned; and the Microfarad Condenser, which is simply a Fizeau condenser of a definite size having a capacity for a 1 microfarad charge, that is a charge equalling $\frac{1}{1000000}$ farad, and represented by about 3,600 square inches of tinfoil. Standard microfarad condensers are costly accessories, their price being as high as twelve guineas; but smaller condensers are frequently used with good effect, and are preferred to Leyden jars on account of compactness, lightness, and portability. A very useful temporary condenser may be constructed of thin sheet glass and tinfoil alternately arranged as in Fizeau's condenser. When we wish to dissect the charge of a condenser, the movable coated Leyden jar must be employed, shown at Fig. 100 in § 44. When this has been charged and placed on an insulating stand of glass, each part may be removed and tested separately with a proof plane, when it will be found that both inner and outer coating has been charged, and also that the glass itself takes and retains a charge of electricity.

§ 47. **Electrical Machines.** After some practice with an electrophorus in charging Leyden jars and condensers, we shall find the experiment somewhat tedious and laborious, because it takes a great deal of time and labour to get even a moderate charge into a Leyden jar from an electrophorus. We shall also desire a more continuous current than can be obtained from jars and condensers with their momentary discharges. This has been the experience of experimenters who have passed

over to the great majority, and left to us the fruits of their labours. One of these fruits is seen in the electrical influence machine of the present day, which is a development by evolution of Volta's electrophorus, Bennet's doubler, Nicholson's revolving doubler, Cavallo's multiplier, and the first improvements of these

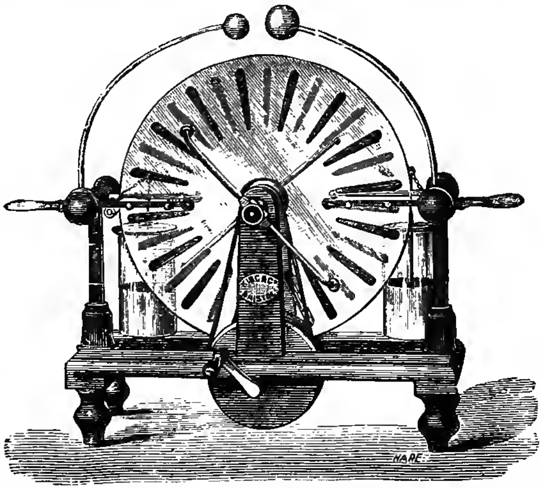


Fig. 119. Wimshurst Electrical Influence Machine.

machines by Hachette, Desormes, Wilson, Ronald, Belli, and Goodman. The time taken in this evolution extended from 1840 to 1875, at which time only a small advance had been made in the construction of generators of static electricity. Faraday's investigations during a period extending from 1831 to 1857, were conducted with rudely constructed apparatus when compared with

the finished machines of the present day. Little progress was made from 1840 to 1860, when Mr. Varley brought out his plate electrical machine for multiplying and doubling the rapidity of electric charges. In 1865 the subject was taken up by Toepler and Holtz in Germany, and the machines made by those gentlemen show a distinct advance in the development of electrical influence machines. The Holtz machine received attention from Poggendorf, Reiss, Kundt, Leyser, Bleekrode, Ruhmkorff, Voss, and others, all of whom added to, or improved the machine as they thought fit; but it was left to Mr. Wimshurst to perfect the work commenced by Holtz, and bring out the now celebrated Wimshurst Electrical Influence Machine, an illustration of which is given at Fig. 119.

It is not my intention to attempt a description of even one type of these machines, since the subject has been most fully dealt with in two books of this series, viz., "Electrical Influence Machines," by J. Gray, and "Electrical Instrument Making for Amateurs," by S. R. Bottone.

Readers desirous of making one of these machines may be glad to know that prepared material for the purpose, in the form of glass plates, ebonite discs, spindles, pillars, and other parts of the machine may be obtained from dealers at reasonable rates. The prices of Wimshurst machines vary from £1 10*s*. for the smallest size, up to £24 for large machines, with six 30-inch plates, capable of giving over 12-inch sparks in air.

§ 48. **Working Electrical Influence Machines.** In the ordinary cylinder electrical machines, and also in those plate machines constructed after the inventions of Holtz, Ramsden, Winter, and Cuthbertson, the electricity is generated by friction, and it is necessary to keep every part dry and warm. The least moisture on their plates conveys away the charge, and it is therefore necessary to well rub the plates with a dry and warm silk handkerchief before working the machine. The rubbers must also be kept well charged with electrical amalgam, and an initial charge given to the plates by holding an electrified piece of ebonite to them. The Wimshurst influence machines require no such preparation or care. If the parts are dry and free from dust, the machine will generate electricity, and discharge sparks freely after a few turns of the handle. If from any cause the machine does not readily charge itself, a gentle rub with a silk handkerchief on one or both pillars will provide the necessary start. The following instructions for adjusting and working the Wimshurst electrical influence machine are given in Mr. Gray's book, before mentioned: "It is important that the metal brush should be in absolute metallic contact with the neutralizing rod. The brushes on the opposite sides of the neutralizing rods must touch the sectors on opposite sides of the centre of each plate at the same time. If the rods are not of the proper shape to cause the brushes to touch the sectors in this way, they should be bent into the proper shape.

"In the two-plate machine the neutralizing rods

should be made to turn on their axis, so that they can be set to different angles. The best position for these rods can be found by experiment. The rule given by Mr. Wimshurst is as follows :—Take your watch, hold it by the chain, and let its back come to the spindle on which the discs revolve: the neutralizing rod for the front disc should then be parallel with the line joining XI and V, and the rod at the back of the machine seen through the glasses must be on the line joining I and VII; that is, the two rods will make an angle with one another of 60 degrees. The above is the best position, though, if the machine does not seem to pick up its charge readily, the rods may be turned into a more horizontal position, say to an angle of 90 degrees. This rule also applies to multiple plate machines. The brushes must be kept in good condition and clean. If they are worn out or are corroded, replace them with new ones." The bearings of the machine should be oiled occasionally with a small quantity of sperm oil. The supports should be tested for insulation by trying to send a spark through them to earth from a charged Leyden jar. If the spark traverses their surface, they should be washed in a solution of carbonate of magnesium, then carefully dried. Connections should be made between the machine and experimental apparatus with stout copper wire, No. 16, well coated with gutta-percha, all ends being bent round, and no points left projecting. It is very important to keep the machine free from dust, because all dust causes points by which the charge escapes.

§ 49. **Charging Leyden Jars from an Electrical Machine.** To charge a Leyden jar from the ordinary electric machines, it may be held in one hand to the prime conductor of the machine as long as sparks pass from the machine to the jar. If the jar is held with the fingers clasping the outer coating and the knob presented to the machine, its inner coating will be positively charged, and the outer coating receive a negative charge. If the jar is held by the knob, and its outer coating presented to the machine, the outer coating will receive a positive, and the inner a negative charge. The jar, or a battery of jars, may be charged without holding them in the hand, if the opposite coating is connected to earth by a length of brass chain.

Wimshurst machines are usually accompanied by two Leyden jars. These rest in two tin cups on the stand of the machine, with the rods and balls of the inner coating resting against the prime conductors of the machine. When it is desired to charge a Leyden jar to obtain discharges from it, the jar must be placed on an insulating stand coated with tinfoil, and connected to one of the conductors by a piece of brass chain, whilst the knob is connected by a similar length of brass chain to the other conductor. In large jars, when thus connected, the discharges take place with short, loud sparks of great brilliancy. If spotted jars —that is, those coated with diamond-shaped patches of tinfoil—be charged in this way, the effects of sparks passing between the patches are very beautiful.

§ 50. **Experiments with Electrical Machines.** Although a wide range of electrical experiments may be performed with an electrophorus, and with charged Leyden jars, and with charged condensers (a selection of such experiments has already been given), there are some experiments requiring a steady stream or flow of electrical effects, such as those obtained from an induction coil, and these can only be obtained from an electric machine in action.

Fig. 120. Arrangement of Tinfoil Specks on a Spangled Tube.

Fig. 121. Spangled Tube.

1. *Luminous Tube.* Procure a glass tube about 3 feet in length, fit a brass cap at each end, and in one of these fix a bent piece of brass wire terminating in a brass knob. This done, cut out a number of lozenge-shaped pieces of tinfoil, and paste them on the tube to form a spiral chain, with short intervals between the pieces, as shown at Figs. 120, 121. When this tube is held in one hand to the prime conductor of an electric machine whilst in action, bright flashes of light

will pass from one piece of tinfoil to another, and thus form a brilliant spiral of light.

2. *Luminous Pane.* Procure a pane of glass, two lead balls, two glass rods half the length of the pane, a heavy slab of mahogany to form a support for the pane in a vertical position, and some sheets of tinfoil.

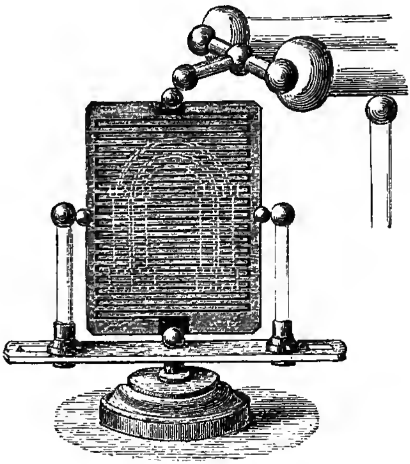


Fig. 122. Luminous Pane in connection with Prime Conductor of Electric Machine.

Cut a number of strips of tinfoil $\frac{1}{8}$-inch wide and 1 inch shorter than the width of the pane, then paste them in parallel lines across the pane, commencing $\frac{1}{2}$-inch from the top edge, and pasting the strips $\frac{1}{4}$-inch apart. Connect the ends of these strips alternately with short pieces of tinfoil, so as to form one continuous zigzag line from

top to bottom of the pane. At the top, paste a piece of foil to connect the upper strip with a split lead bullet placed on the edge of the pane, and at the bottom, paste a similar piece for the same purpose.

When the foil is dry and firmly adherent to the glass, take a sharp penknife, and cut out $\frac{1}{8}$-inch gaps from the strips of tinfoil to form a design, such as the figure of a man, the outline of a flower, or of an animal, or of a church window, or of a portico, or of a word. This done, mount the pane in a vertical position on the polished slab of mahogany supported on each side by the two glass rods. The feet of these rods must be cemented into sockets cut in the mahogany to fit them, and the pane of glass is to be held in notches cut in two polished hardwood balls mounted on the tops of the pillars.

The experiment with this apparatus is performed in a darkened room. The top lead bullet is placed in connection with the prime conductor of the machine, and the lower lead bullet by a piece of chain with the earth or floor of the apartment. When the machine is in motion, flashes of light will break across the gaps cut in the strips of tinfoil, and the outline of the device or word will appear in beautiful scintillations of light.

A number of such panes may be prepared, each with a different device, and each pane may be framed in mahogany well soaked in paraffin wax. When constructed in this form, the connections may be made with pieces of wire passing through the frame and

terminating in hooks with brass knobs at the ends of the hooks. The frames may be mounted on a suitable insulating stand during the experiment, and can thus be changed as magic-lantern slides are changed. This method of mounting is preferable to that of a fixed pane.

3. *Luminous Eggs.* The discharge from an electric machine may be made to pass through eggs, which are thereby rendered luminous in a darkened room. The apparatus for this purpose consists of two parallel pillars of turned and polished mahogany standing on a heavy hardwood base, with rings of wood between them to form supports for the eggs. A short spiral of wire, terminating in a hook and knob, is fixed to the slab between the pillars, and in this spiral rests one end of the first egg, whilst its upper end is supported in one of the wooden rings; the next egg is supported in another wooden ring above it, with its lower end touching the top of the first egg; another may be placed above this in a similar manner, the upper part of the top egg resting against a spiral of wire, the stem of which passes through a cross piece of wood connecting the tops of the pillars, and terminates in a hook and a knob. The lower hook is connected by a piece of chain with the ground or floor, and the upper hook with the prime conductor of the machine.

4. *Luminous Jar.* A Leyden jar is prepared in the ordinary way except a coating of tinfoil on the outside. A substitute for this is provided in the form of a narrow band of foil around the top, and another narrow band

around the bottom, the space between being coated with varnish, then rolled in brass filings whilst the varnish is wet. The lower band of foil is placed in connection with a thin disc of tin under the jar, to which a wire hook is soldered. The upper band has a strip of tinfoil connecting it with a small round disc of the same material on the neck of the jar. The rod of the jar terminates in a hook, which is bent over until its terminal knob nearly touches the tinfoil spot on the neck. When this jar is hung on the prime conductor of a machine, and a piece of clock-chain is fastened to the hook beneath the jar to make connection between it and the floor, the jar becomes charged on setting the machine in action, and then discharged through the knobbed hook and outer coating. The discharge is very interesting, as the spark leaps from the knob of the hook to the tinfoil spot on the neck of the jar, then the charge spreads out into a number of bright sparks, which traverse the filings on the outside, and produce a very pretty effect.

5. *Miscellaneous Luminous Effects of Electric Discharges.* With current from a good Wimshurst electrical influence machine, some beautiful effects may be produced in Geissler and other so-called vacuum tubes, the apparatus being connected to the terminals of the machine through lengths of guttapercha-covered wire. Tesla's experiments, as detailed in § 33, may be easily imitated by holding vacuum tubes in our hands, and pointing with them to the prime conductors of the machine, when they will be splendidly illuminated, thus

showing that the high-tension current is passing through our bodies in a manner imperceptible to our feelings. A number of tubes held by several persons at various points around the machine whilst at work in the dark, will reveal the fact that it is surrounded by a halo of electric action, in fact that the air of the room is charged with electricity. If gentlemen with hair on their faces, stoop to the prime conductor, beards and moustachios become luminous, and even the machine itself appears bathed in luminous brush discharges. Beautiful

Fig. 123. Aurora Flask.

aurora effects may be obtained by holding an Aurora Flask (Fig. 123) to the machine. Nearly all the luminous experiments performed with current from an induction coil as detailed in Chapter III., including those with the electric egg and Gassiot's cascade, may also be performed with current from a good electrical influence machine.

6. *Heating Effects of Electric Discharges.* All the heating effects of electric discharges, as noticed in Chapter III., when dealing with the induced current

from induction coils, may also be studied by the aid of current obtained from an electrical influence machine, either obtained direct from the machine itself or through the intermediary of suitable condensers and Leyden

Fig. 124. Clark's Patent Statical Electric Gas-Lighter.

jars, as noticed in the sections devoted to these apparatus. Gas may be lit, fuses fired, metal deflagrated, and other heating effects studied by its aid. One of the most useful applications of these machines to heating and lighting purposes is seen in the little influence

machines known as Clark's Patent Electric Gas-Lighter, shown in action at Fig. 124. In this little machine, a high-tension current of electricity is generated by the influence of a revolving ebonite cylinder set in motion by a ratchet arrangement, actuated by pressing a button with the thumb, as shown in the illustration. The current is conveyed to the tip of the stem by insulated

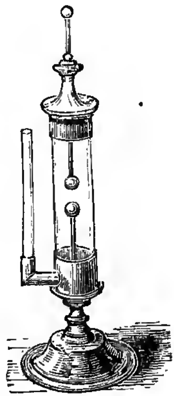


Fig. 125. Kinnersley's "Electric Thermometer."

wires, and there breaks across a short air space in the form of bright sparks. An illustrated description of the interior arrangements of this machine is given in Gray's "Influence Machines," p. 195.

7. *Mechanical Effects of Electric Discharges.* These differ but very little from the mechanical effects of other forces discharged at high pressure. In addition to those already noted in previous sections when dealing

with the discharge from Leyden jars, we may now notice—*a. Kinnersley's Electric Thermometer*, which is shown at Fig. 125, and was supposed to indicate a rise in temperature of the air in the larger cylinder by the passage of the electric spark. As a matter of fact, the discharge of electricity displaces some of the air in the inner tube, and the sudden jerk given to the surface of water in it forces some of the water into the outer tube. *b. The Electric Whirl*, shown at Fig. 126, is merely a pair of crossed wires with their tips bent at nearly right

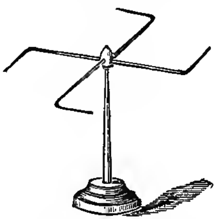


Fig. 126. Electric Whirl.

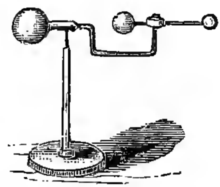


Fig. 127. The Electric Orrery.

angles and delicately poised on a pivot. When this is placed on the prime conductor of a machine, or is connected to it, the positive charge is given off to the surrounding air from the points of the whirl, and this striking the air much the same as steam or water issuing from a pipe at high pressure, forces the whirl around at a high speed. *c.* A similar result is obtained by a different cause in the *Electric Orrery*, shown at Fig. 127. This instrument, as will be seen from the figure, consists of an arm of brass wire with a knob of brass at one end, and another arm of brass

wire carrying two brass knobs at the other end. The first knob is the larger and heavier of the three. The main arm is bent to allow the second arm free play as it turns around on the upturned end on which it is nicely poised. The whole is delicately poised on a sharp point mounted on an insulated stand. When this instrument is placed under the end of the prime conductor of an electrical machine, the large knob becomes positively charged, and is then repelled by the prime conductor. At the same time the second knob is charged similarly to the bend of the arm near it, and is also repelled. The outermost knob is at first in a negative condition, and is thus attracted to the prime conductor, but on approaching it the knob becomes positively charged, when it is repelled. By a succession of such alternate attractions and repulsions, answering to a series of magnetic reversals, the larger ball is caused to revolve on its pivot, and the other balls revolve more rapidly on their pivot, thus resembling the motion of planetary bodies. *d. The Electric See-saw* is another toy illustrative of the law of attraction and repulsion. The figures of two boys or two jockeys are carved out of pith and nicely painted, then glued to the ends of a short and light lath. The centre of this is glued to a piece of brass wire sharpened at both ends to form pivots, and these are mounted in sockets pierced in two brass knobs cemented to the tops of insulating glass pillars secured to a base-board of polished mahogany. Two brass knobs furnished with connecting-hooks are mounted on short insulating pillars beneath the ends of

the lath at both ends of the base-board. One of these must be connected by a piece of brass chain with the prime conductor of the machine, whilst the other is connected by similar means to earth. As the machine is worked, the pith figures will be alternately attracted and repelled, and thus execute a see-saw movement. *e. The Electrical Swing* is similarly constructed, only in this the pith figure swings to and fro between two insulated knobs, on a silken swing suspended to glass pillars. *f. Electric Dancers.* If a number of pith balls

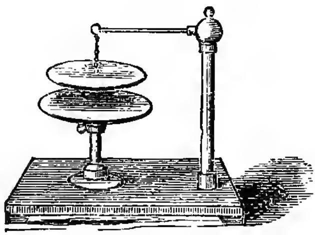


Fig. 128. Apparatus for Electric Dancers.

be strewn on a metal plate and covered with a bell glass receiver having a Leyden jar knob fixed in the top, the balls will rise to the knob when this is connected to the prime conductor of the machine, and will then be repelled to fall on the metal plate. If this plate is connected to earth, a brisk interchange of opposite charges will take place and keep the pith balls in a state of continuous commotion. If, now, two metal plates are provided, as shown in Fig. 128, and a number of grotesquely carved pith figures of men and women

are placed on the lower plate, they will move about in a similar manner and resemble the motions of a dance. *g. Electrical Insects.* By the exercise of a little ingenuity, figures of birds, and butterflies, spiders, etc., may be carved out of pith, and ornamented by light fragments of feathers, then suspended to fibres of cocoon silk between insulated pillars and insulated

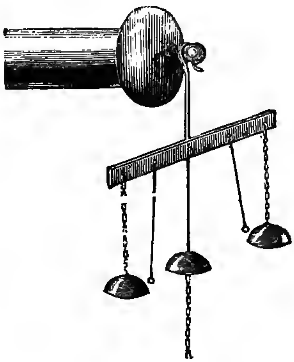


Fig. 129. Electric Chimes.

Fig. 130. Dummy Head of Hair.

plates, to swing, flit, and fly from one to the other as they become alternately charged positively and negatively. *h. Electric Chimes.* By suspending a chime of small bells to the prime conductor of a machine, as shown at Fig. 129, a musical variation may be introduced into the entertainment, as the little brass beads swing from one bell to another under the influence of alternate electric charges.

There are several other experiments which might be enumerated to illustrate the mechanical effects of electric discharges from an electric machine. One favourite method of illustrating electric repulsion, is to carve a figure resembling a human head, and stick on it some real long hair. This hair hangs down lank and limp, as shown at Fig. 130, when the figure is uncharged, but rises up stiff as if the head was frightened, when it is charged by electricity from the prime conductor of the machine. That the discharge causes a displacement of air around the discharging point, may be shown by holding a lighted taper to the prime conductor whilst the machine is at work. The flame will either be drawn toward the machine or blown violently from it, according as the movement of the discharge is negative or positive.

8. *Physiological Effects of Electric Discharges.* The effects of discharges from static electrical apparatus on animal tissues, are precisely the same as those from other generators of electricity. For instance, if we have a Wimshurst electrical influence machine, and wish to test the physiological effects of its discharge on ourselves, we first withdraw the wire from between the two terminals on the stand between the Leyden jars, arrange the discharging knobs to give a spark of only $\frac{1}{8}$-inch, then connect two sponge electrodes by wire cords to the two terminals of the machine. On holding the wet sponges in the two hands whilst a friend turns the machine slowly, a series of gentle shocks will be felt, because the discharge is delivered at

a low tension and divided between the body and the discharging knobs. Now increase the distance between the discharging knobs and turn the handle of the machine faster. The intensity of the shocks will be increased because the increased speed of the machine increases the tension of the current, a higher resistance exists between the discharging knobs, and more current at a higher tension is sent through the body. The severity of the shocks may thus be increased, much the same as those from an induction coil, and become increasingly painful with each increase of tension in the current when the full volume of this has to pass through any part of the body. The current from static electrical apparatus may, however, be divided among several conductors, much the same as that from other generators or storers of electricity, or it may be modified by resistances, and thus the severity of the shocks be mitigated. When the body is placed on an insulated stool—that is, a stool supported on glass legs (a piece of wood supported by four reversed glass tumblers will serve the purpose)—and is connected with the prime conductor of the machine, it may be charged with electricity much the same as any other condenser, and the hair on it will stand out in a state of mutual repulsion, as that on the dummy head previously mentioned. When a person is thus charged, sparks may be drawn from any part of his body, or he may light the gas by pointing his finger to the burner. A very interesting experiment to young people may now be performed, which may be named *The Electric Kiss.* The

person charged, may challenge a member of the opposite sex to dare to steal a kiss. If the challenge is accepted, the kiss will be delivered with a stinging effect, and both will agree that they have never before received such a warm osculatory salute.

Experiments of this kind with Leyden jars are not to be recommended. Shocks may be taken from very small jars of ½-pint size, but it is neither safe nor pleasant to receive shocks from large jars or batteries of jars, nor should their charge be delivered to individuals without due warning as to what to expect from them. Although much amusement has been obtained from shocks delivered from Leyden jars to unwary individuals, it must be conceded that they are rarely received voluntarily after the first experience, and most persons regard them as they would donkey's kicks—more pleasant to administer than to receive.

§ 51. **Remarks on Electro-Static Experiments.** In the previous sections of this chapter, I have mentioned a large number of the most interesting experiments performable with electro-static apparatus, but many others remain to be described, for which I cannot find space in this book. In nearly every text-book treating of electricity and magnetism, there will be found a description of experiments demonstrating the lessons and laws of these sciences. Some of these experiments differ from those I have mentioned here, and some necessitate the use of high-priced apparatus only found in well-appointed laboratories or owned by rich persons. A series of splendidly illustrated articles on experiments

with vacuum tubes appeared in the *Electrician*, vol. xxvi.; and a long series of letters on "Experiments in Electro-Statics," many of which are very interesting, may be found in the *English Mechanic*, vols. lv. and lvi.

Experiments with electro-static apparatus, are also described in Mr. Perren Maycock's "First Book of Electricity and Magnetism," and in Mr. Bottone's book on the same subject, both published by Messrs. Whittaker & Co.

CHAPTER V.

ELECTROLYTIC EXPERIMENTS.

§ 52. **Electrolysis.** This term means, literally, "breaking up by electricity," and was first employed by Faraday to express the effects of an electric current on water when passing through it, the effects, as observed by him, being a breaking up of water into two separate elements. Water is composed of the two elementary gases, oxygen and hydrogen, intimately united and blended by chemical affinity to form a liquid. These two elements may be separated by passing a strong current of electricity through water, when this liquid is said to be decomposed by electrolysis. Water is therefore a compound body, made up of two other bodies. When a body is thus compounded, its smallest portion—that is, the smallest part into which it can be divided (in water, for instance, the very smallest drop or particle)—is named by chemists a "molecule," and this molecule is made up of "atoms," each atom representing a separate element. As water is not the only compound substance met with, the other compound substances may be broken up by electrolysis, just the same as water is electrolysed. Some compound substances may be electrolysed whilst in a state of fusion,

or in a molten condition at a high temperature; but, as a large number of compound substances may be rendered soluble in water, it is usual to employ a watery solution of them for electrolytic purposes, and such solutions are named electrolytes. In the experiments about to be described, the electrolytes will be watery solutions of compound substances.

§ 53. **Electric Current Required for Electrolysis.** Compound substances may be broken up and their elements separated by means other than that of electrolysis, but it is clear that no electrolytic effects can be produced without the use of an electric current. Although electric action accompanies chemical methods of decomposing compound substances, these methods are not generally termed electrolytic, the latter term being reserved to express decomposition by a separate electric current. The electric current required to electrolyse a compound substance, varies with the nature of the substance under consideration, and is determined by the strength of the bonds of chemical affinity binding the atoms together in molecular form. When the atoms have not a very strong affinity, they may be separated by a feeble electric current. Stronger bonds will need a stronger current to break them. Almost any generator of electricity may be employed to furnish electric current for electrolytic purposes, the principal exception being those machines which generate alternating currents of equal duration—that is, those furnishing a current in one direction, and a current in the opposite direction alternately—say, for illustration, one moment

negative and the other moment positive. Such currents may be used in electric lighting and for some other purposes, but not for electrolysis. Electrolysis of liquids may be effected by irregular currents, such as those from an induction coil. Although these are somewhat of an alternating character, the alternations are not of equal duration and force, as we have already seen in dealing with them for experimental purposes. Electrolysis may also be effected by current from all static electrical machines except the alternating influence machines. The most convenient generator of current for this purpose is, however, a small dynamo electric machine driven by hand power. This, for small and short experiments, is handier and cleaner than a primary battery. If required for longer experiments, it should be driven by a belt from a gas-engine, oil-engine, water-motor, model steam-engine, or other similar source of motive power. Small dynamos suitable for this purpose are described and illustrated in Mr. Bottone's books, "Electrical Instrument Making,"[1] and "The Dynamo: How Made and How Used." Next to dynamo electric machines, may be classed primary batteries as generators of current, those most suitable for working induction coils being also best for this purpose. These are fully described in "Induction Coils,"[1] chapter vi.

§ 54. **Electrolysis of Water.** This has already been described, under the head of *Decomposition of Water*, in § 29, where an apparatus for use with induction coils has been noticed. By the use of the appara-

[1] Published by Whittaker & Co., price 3*s*.

tus illustrated at Fig. 132, and a constant current having an E.M.F. of from 2 to 4 volts, the quantitative and qualitative analysis of water by electrolysis may be attempted. The apparatus consists of a mahogany slab on which rests a glass vessel with two holes drilled through the bottom for the admission of two strips of platinum connected to the two binding screws seen on the base of the apparatus. The glass vessel, being made water-tight, is partly filled with water acidulated

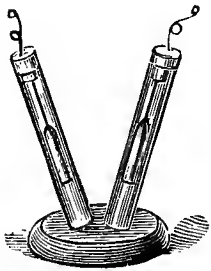


Fig. 131. U-Tube Voltmeter.

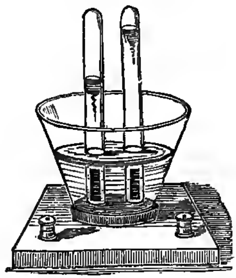


Fig. 132. Voltmeter on Stand.

with a small quantity of sulphuric acid to render it a better conductor, because water itself is a bad conductor of electricity. Two glass test-tubes partially filled with some acidulated water are now inverted over the platinum strips, as shown in section at Fig. 133. When the two binding screws are connected with the battery or other source of electricity, bubbles will be seen to form on the surfaces of both platinum strips and pass upward through the water to its surface. As the action is continued, the water in both tubes will be displaced by the

gases given off from the platinum strips, but the greatest apparent displacement will have taken place in the tube connected to the zinc element of the battery, or to the negative pole of the machine. This tube will contain hydrogen, whilst the opposite tube, connected to the positive pole of the generator, will contain oxygen. The relative volumes of both gases should be two of hydrogen to one of oxygen; but this cannot always be exactly ensured with the apparatus above described, although the results obtained will *appear* in the above

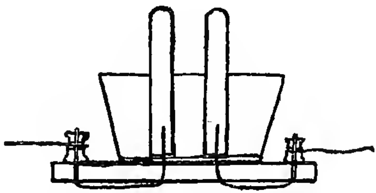


Fig. 133. Section of Voltmeter.

ratio. Discrepancies are caused by the fact that large platinum electrodes hold some of the hydrogen obtained from the water, and some of the oxygen liberated in the opposite tube is dissolved in the water. With a stronger current than is absolutely necessary to decompose the water, ozone is liberated with the oxygen, and some peroxide of hydrogen is also decomposed at the expense of some of the liberated oxygen. For exact results, therefore, the decomposing apparatus must have small electrodes of platinum wire, the water must be carefully prepared and the current must be con-

trolled, to prevent an excess of ozone being formed. The E.M.F. of the current for exact results should not greatly exceed 2 volts.

If the two platinum wires project into one tube, the water in that tube will be decomposed, but the separated gases will unite again, forming a mixture of hydrogen and oxygen. A small apparatus for thus decomposing water, and showing that an electric current is generated in a chain electric belt, is used by J. Pulvermacher & Co. It consists of a small test-tube with two holes drilled through the bottom, through which two thin platinum wires are inserted at distances of $\frac{1}{8}$-inch apart, sealed in position by sealing-wax. The interior ends of these wires stand up in the tube to the length of $\frac{1}{2}$-inch, and the exterior ends are soldered to two thin strips of brass for connection with the belt. As the resistance is very small in acidulated water between electrodes so closely placed, bubbles of gas are given off from the ends of the platinum wires when the links of a belt are connected to them, although the current has only an E.M.F. of 1·50 volts.

A measuring instrument used for measuring electric force, its construction based on the discovery by Faraday that water could be decomposed by an electric current, was invented by him, and named (in honour of Volta) the voltameter, or measurer of voltaic electricity. It has been found that the quantity of hydrogen given off from the negative pole of a battery in a given time is in direct ratio to the strength of current passing through the acidulated water con-

tained in the instrument. The equivalent quantity of oxygen given off from the opposite pole is also governed by the same rule. Now, as the quantity of electricity passing through a resistance of one ohm in one second, will liberate ·000158 grain of hydrogen, and one grain of hydrogen will occupy 46·73 cubic inches of space, the volume of current can be easily ascertained by noting the displacement of water by the liberated hydrogen, and calculating the weight of the hydrogen by the foregoing rule. The equivalent weight of oxygen liberated from the opposite pole in the same time will be ·001264 grain, and one grain of this gas, owing to its greater density, will only occupy 23·36 cubic inches of space.

The voltameter may be constructed with two tubes filled with acidulated water, inverted over platinum electrodes so as to collect and measure the gases separately, or (and this is the usual form) the two electrodes may be contained in one glass tube, and the mixed gases measured. The tube may be etched in graduated marks to show at once the volume of gas liberated, or the decomposition may be effected in a separate glass bottle furnished with an air-tight stopper through which passes a bent glass tube leading to a glass collector inverted in a trough of mercury, and marked with etched graduations to indicate the volume of mixed gas liberated in the larger vessel.

§ 55. **Electrolysis of Coloured Fluids.** Procure a glass tube, from 12 to 15 inches in length, and having a bore of from $\frac{3}{4}$ to 1 inch. Carefully warm it in the

middle by revolving it in the flame of a Bunsen burner, hold it there until it has become red hot, then bend it gradually to the form of the capital letter U, then let it cool gradually without touching any cold substance. When cool, cement tho bent part in a groove cut in a heavy slab of mahogany to form a stand for the instrument. This is named a U-tube, and is useful for electrolytic experiments. Tubes thus bent, mounted and furnished with a pair of platinum electrodes, cost from 4*s*. to 5*s*. The following experiments will be interesting.

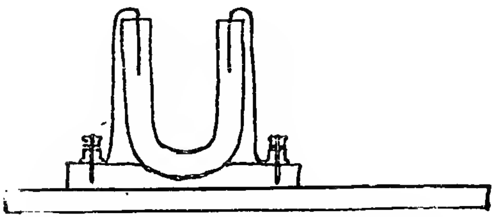


Fig. 134. Sectional Elevation of a U-Tube.

1. Dissolve ¼-oz. of sulphate of potash in clear water, and add enough tincture of violets to render the liquid a beautiful blue tint. Place this liquid in a U-tube, immerse the platinum electrodes, and connect them to a source of electricity giving a pressure not exceeding 2 volts. The current from a Smee cell will be most suitable, or a cell made of a glass tumbler, or even a porcelain cup containing a copper and a zinc plate immersed in acidulated water. As soon as the electrodes are connected to the battery, the liquid in the

limb containing the positive electrode will assume a red tint, whilst that in the opposite limb will appear green. This change of colour is due to decomposition of the liquid by the electric current, the sulphate of potash being broken up into its constituent parts of sulphuric acid and potassium. Sulphuric acid is liberated around the positive pole, and this reddens the tincture of violets, whilst potassium is determined to the negative pole, and there unites with hydrogen to form potash, and this gives a green tint to the solution. If the battery power is increased, oxygen will be given off from the positive pole, and hydrogen from the negative pole.

2. Procure a very thin and dilute solution of starch in water, and dissolve therein a few grains of iodide of potassium. Place this in the U-tube and connect the electrodes to a battery as before mentioned. Iodide of starch will be formed at the positive pole, and will give the solution a beautiful purple tint, whilst potassium will be determined to the opposite pole, but will not affect the colour of the solution.

3. Repeat the experiment with common salt dissolved in water, and tinted with sulphate of indigo. Chlorine will be liberated at the positive pole, and this will bleach the indigo solution, whilst the solution in the opposite limb is unaffected.

4. Repeat the experiment with nitrate of potash dissolved in water and tinted with tincture of litmus. Nitric acid will be liberated at the positive pole and tint the solution red in one limb, whilst the other remains unaffected. All the foregoing experiments may

be varied by using a square glass trough divided in two equal parts by a porous diaphragm, or by a piece of cardboard, each part being filled with equal quantities of the solution and furnished with platinum or with carbon electrodes. The dividing line of the two fields of action and of influeuce will be strictly defined by the porous partition. These experiments may be employed to teach one of the fundamental laws governing electrolysis; viz., that the acid radical is always set free at the positive pole, and the base of the molecule is determined to the negative pole. This can be proved by sight in a tinted solution.

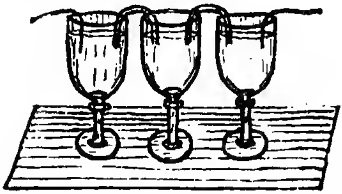


Fig. 135. Wine-glass Experiment.

5. Procure three wine-glasses or three similar glass vessels, nearly fill them with the sulphate of potash solution made for experiment 1, and place them side by side. Soak some threads of soft cotton or of asbestos in the same liquid, and use two tufts of this material to bridge over the edges and spaces between the central glass and the two side glasses, as shown in Fig. 135, so that the ends of the cotton dip into all three glasses. Now place one platinum electrode connected to the battery in one end glass, and the other

electrode in the other end glass. The current from the battery will traverse the whole series of glasses by the wet threads, and the results shown in experiment 1 will be repeated, the liquid in one glass turning red, that in the opposite glass assuming a green tint, whilst that in the centre glass remains unaffected. The central glass may be filled with dilute sulphuric acid by way of varying the experiment, when of course it will be colourless, and be unaffected by the action going on in the other glasses. Another and more delicate variation may be adopted by charging the glass in which the negative electrode is immersed with sulphate of soda, the central glass with dilute sulphuric acid, and the positive end glass with a solution of tincture of violets, then connect the whole by means of cotton threads dipped in the sulphate of soda solution. After being connected to the battery for a short time, the positive glass will assume a red tint, the negative a green tint, whilst the central glass remains unchanged. This shows that the moist threads of cotton act as syphons, and carry over into the end glasses some of the contents of the central glass when an electric current is passing through them.

§ 56. **Electrolysis of Metallic Salts.** When an electric current of sufficient strength to decompose the salts in solution is sent through a solution of metallic salts, the metal base of the molecules is deposited on the negative pole, and the acid or alkaline radical is set free at the positive pole. Thus, if we make a solution of copper sulphate, the metallic salt in solution is

composed of the metal base, copper, represented by the symbol C_u, and the radical, sulphuric acid, represented by the symbol $H_2 S O_4$. When this salt is decomposed by the electric current, copper is deposited on the negative pole, and sulphuric acid is set free at the positive pole. If the positive pole is of copper, it becomes oxidized by oxygen set free from the solution by electrolysis, and the radical $S O_3$ at once enters into combination with the oxidized copper to form copper sulphate. If we employ a solution of a metallic chloride, the metal is deposited on the negative pole, and chlorine is set free at the positive pole. If we employ a solution of double cyanide of gold, silver, or copper, the radical cyanogen is set free at the positive pole and the metal at the negative pole. This order is always observed: the metal is always deposited on the negative pole, and that which enters into combination with the metal to form a metallic salt, is set free at the positive pole. The positive pole of an electro-depositing arrangement is named an "*anode*," from Greek words meaning the "way into" or "down into," because it is the way by which the electric current passes from the generator *down into* the solution to be electrolysed. The negative pole is named a "*cathode*" or *kathode*, from Greek words meaning the "way up" or the *way out of*, because it is the way by which the electric current passes out of the solution back to the generator. Anodes and cathodes must be conductors of the electric current, and are usually in the form of plates or strips of metal suspended in the solution to be electrolysed. Anodes may be

insoluble in the electrolyte, as when platinum is employed in a solution of copper sulphate, or they may be soluble in the solution, as when copper is employed as the anode in this solution. Cathodes may be of the same metal as the anodes, or an entirely different metal, but they must not be soluble in the electro-depositing solution if an adherent deposit is desired. The electro-depositing solution, or the solution to be electrolysed, is named an electrolyte, and the conducting constituents of this solution are named "ions"; hence those which are liberated at the anode are termed "anions," and those at the cathode, "cations." Metallic salts in solution may be decomposed by an electric current, but the strength of current necessary to effect the decomposition will vary in proportion to the bond of affinity holding the base to its radical, and the affinity of this for any other base introduced into the solution. When the bond of affinity is so weak as to allow of decomposition by the immersion of another metal in the solution, the deposit of metal from the solution is said to be effected by simple immersion, and is simply brought about by chemical action in an interchange of elements. A list of experiments performed by Mr. George Gore with various metals in various solutions, to find those effected by simple immersion, have been published in his book on "Electro-Metallurgy," and a tabular list of similar experiments may be found in the "Electro-plater's Handbook," at p. 9, § 12.

§ 57. **Simple Electro-Deposition of Metals.** When two metals are immersed in a metallic solution capable

of dissolving one of the metals, and the two are connected by a wire above the solution, an electric current is generated, and metal is deposited from the solution on that metal which forms the electro-negative element of the pair. This is shown by the following experiments.

1. *Deposition of Copper.* Crush ½-oz. of copper sulphate (the "bluestone" of commerce), and dissolve it in ½-pint of hot water. Allow this to cool, then put it in a glass tumbler. If we immerse a rod of iron, steel, or zinc in this solution, either of those metals will be coated with copper by simple deposition; but if we place a brass rod in connection with zinc, the brass rod will receive a coat of copper, although brass by itself will not become coated in this solution. If also we employ rods or strips of sheet silver, german silver, tin, or platinum connected to an opposite piece of iron or steel, these metals, being electro-negative to iron and steel in this solution, will receive a coat of copper by electro-deposition. It may be noted here, however, that although brass is electro-positive to platinum, it is not sufficiently so to cause a deposit of copper on platinum when both are immersed as a pair in a sulphate of copper solution. If oxide of copper is dissolved in liquor ammonia, zinc will deposit copper from this solution on platinum. A very beautiful experiment can be performed with a solution of the acetate or the sulphate of copper, a polished silver plate, and a rod of zinc. If a drop of the copper solution is placed on the silver plate and then touched with the point of the zinc

rod, a series of dark and light rings will be formed around the point of contact, and produce a very pretty effect on the silver plate.

2. *Deposition of Silver.* Simple deposition of silver by chemical interchange, occurs when copper, or zinc, or common brass is immersed in a solution of silver salts, the radical of which has an affinity for the immersed metal. For instance, as the radical cyanogen has an affinity for copper and zinc, these metals become coated with silver in a solution of the double cyanide of silver and potassium (the ordinary plating solution), and as the radical $N\,O_3$ has an affinity for copper, zinc, and brass, these metals become coated with silver in a solution of silver nitrate. Some very pretty experiments in silver deposition may be effected by means of a solution of silver nitrate, among the most interesting being the formation of a "silver tree" named *Arbor Dianæ,* or "Tree of Diana." The following methods may be employed, producing as many variations of this beautiful experiment. *a.* Dissolve $\frac{1}{4}$-oz. crystallized nitrate of silver in 1 pint of distilled water contained in a glass globe or decanter, and suspend in it from the mouth by a piece of copper wire, a small lump of zinc, with branches of copper wire. Set it aside in a corner where it will be free from disturbance, as on a corner bracket, and in a short time the wires will be coated with beautiful silver moss. *b.* Procure 6 dwts. of mercury and 2 dwts. of silver filings, and rub them together in a mortar. Dissolve 5 dwts. of nitrate of silver in 1 pint of distilled water, and add to it 3 dwts. of mercury dissolved in half a tea-

spoonful of nitric acid. Now add the mercury and silver amalgam, which will fall to the bottom of the vessel, and form the basis of a splendid arborescent growth of silver crystals. *c.* Into a dilute solution of silver nitrate as prepared for experiment *a*, pour ¼-oz. mercury. Crystals of pure silver will be precipitated on the globules of mercury. *d.* Add a small quantity of nitrate of mercury as prepared for experiment *b*, to a decanter filled with dilute silver nitrate solution. *e.* Immerse clean strips of copper foil cut and twisted into fantastic forms of trees in the nitrate of silver solution. Silver crystals will rapidly form on the copper and produce a magic arborescent growth. *f.* Procure a plate of polished copper, and trace thereon with a camel-hair pencil the form of a tree. The skeleton will be rapidly clothed with silver leaves. *g.* Dissolve 15 grains of silver nitrate in ½ a dram of distilled water, and make a small pool with it on a piece of clean window glass placed level on a table or shelf, in a secluded place free from disturbance, then put several pieces of bright copper foil with their ends just touching the pool at various points, and allow the whole to rest undisturbed for some three or four hours. At the end of that time, the spots in contact with the metal will be coated with a fine white crystalline precipitate of pure silver.

In all these experiments, the radical $N\,O_3$ of silver nitrate has a greater affinity for the other metals than it has for silver, and therefore leaves it to combine with these metals, thus setting the silver free.

In solutions of silver nitrate, and also in cyanide of

silver-plating solutions, all metals electro-negative to copper and zinc, become coated with silver when connected together to form electro-negative and electro-positive pairs respectively.

3. *Deposition of Lead.* With a dilute solution of lead acetate in distilled water, some beautiful arborescent growths (named lead trees) may be produced by means similar to those detailed at *a* in the preceding sub-section, using zinc and brass wire only as the foundation for the growth. Zinc will also receive a coating of lead in a solution of nitrate and hyponitrate of lead. In these solutions also, metals electro-negative to zinc receive a deposit of lead when connected with zinc to form a pair.

A very beautiful experiment with a lead salt, and a special decomposing apparatus, may be performed as follows. Dissolve 2 ozs. of caustic potash in 1 quart of distilled water, then add 2 ozs. of litharge, and keep the mixture at boiling point for half an hour. Allow it to cool, pour off the clear portion, and make it up to 1 quart with distilled water. Pour this in a glass vessel and immerse in it a polished plate of german silver as a cathode, and a platinum wire embedded in glass, all except the tip, as an anode, connected to a source of electricity having an E.M.F of 15 volts, which will be represented by eight Bunsen cells in series. The anode should be placed with its point close to the polished plate, and the beautiful results watched. If the arrangement of anode and current are suitable, the lead salt will be decomposed into metallic lead and the per-

oxide of lead, and both will be deposited in many-coloured iridescent rings on the polished plate, the richest colours of the rainbow being represented. These rings are known as Nobili's rings, from the name of their discoverer. If the current is too strong, only brown patches are deposited.

4. *Deposition of Bismuth.* A beautiful precipitate of metallic bismuth may be obtained from a solution of 20 grains of nitrate of bismuth in a wine-glassful of distilled water, by immersing therein a strip or rod of bright copper. Zinc, tin, lead, and iron will deposit bismuth on themselves in a solution of chloride of bismuth; and brass in contact with zinc, copper in contact with tin, or german silver in contact with iron, all receive a deposit of bismuth in this solution.

5. *Deposition of Mercury.* With a solution of mercury in nitric acid, and also with salts of mercury combined with chalk to form a paste, some experiments may be performed which savour of the pretensions of alchemists. By dipping an iron nail into a solution of copper sulphate, it will become coated with copper, and this may be made to assume the appearance of silver by dipping the copper-coated nail into a solution of nitrate of mercury. Unscrupulous itinerant vendors of cheap plate powders, frequently deceive the uninitiated and gullible public, by rubbing a copper or brass article with similar mercury-charged powders and pretending that these deposit a coat of pure silver on the article! Mercurous salts yield metallic mercury to antimony, bismuth, cadmium, copper, iron, lead, tin, zinc, brass, and alloys of silver

with these metals. Nitrate of mercury will yield its metal to antimony, bismuth, brass, cadmium, copper, iron, lead, and zinc. In a solution of this salt, silver will receive a deposit of mercury when connected to zinc or iron, and platinum when connected to copper.

6. *Deposition of Iron.* In a saturated solution of the protosulphate of iron, platinum will receive a deposit of iron when connected to zinc.

7. *Deposition of Tin.* In a solution of chloride of tin, zinc and lead become tinned, and antimony, tin, or copper, receive a coating of tin when connected to zinc.

8. *Deposition of Nickel.* In a solution of the double chloride of nickel and ammonium, copper connected to zinc will receive a coating of nickel.

9. *Deposition of Platinum.* In a solution of tetrachloride of platinum, the metal is deposited on platinum connected to zinc.

10. *Deposition of Gold.* In a solution of terchloride of gold, all metals electro-positive to gold deposit this metal on themselves. In a solution of double cyanide of gold and potassium, copper, brass, german silver, and zinc will coat themselves with gold, and all metals electro-negative to zinc when connected to this metal.

§ 58. **Single-Cell Electro-Deposition of Metals.** When two metals are connected together in two separate solutions separated by a porous division, and metal is electro-deposited on the electro-negative metal of the pair, the process is named "the single-cell process" of electro-deposition. By this process some beautiful works of art have been produced in electro-deposited copper, and

the most constant voltaic battery yet discovered owes its existence to the principles involved in this process.

The following experiments with an arrangement described on the opposite page, have been given by Mr. G. Gore in his book, "Electro-Metallurgy," and are reproduced here in tabular form.

EXPERIMENTS BY MR. G. GORE.

ARRANGED IN TABULAR FORM.

Metal.	Top Solution.	Bottom Solution.	Result.
Antimony.	Dilute Hydrochloric Acid.	Sulphate of Copper.	Deposit of Copper.
Bismuth.	" " "	Chloride of Bismuth.	Deposit of Bismuth.
"	Dilute Nitric Acid.	Nitrate of Bismuth.	Thin Deposit in 12 hours.
Brass.	Dilute Sulphuric Acid.	Sulphate of Copper.	" " "
Copper.	Dilute Hydrochloric Acid.	Chloride of Copper.	Deposit of Copper.
Silver.	Cyanide of Potassium.	Silver-plating Solution.	Deposit of Silver.
Tin.	Dilute Hydrochloric Acid.	Chloride of Tin.	Deposit of Tin.
Zinc.	" " "	Chloride of Zinc.	Deposit in 12 hours.
"	Dilute Sulphuric Acid.	Sulphate of Zinc.	" " "
"	" " "	Acetate of Zinc.	Deposit of Zinc.

It is possible in some cases to dispense entirely with a porous partition when conducting experiments, the two liquids being separated by the difference in their specific gravity, the heavier liquid being poured into a tall glass first, and the lighter liquid so introduced as to float above the first. This may be done by floating a cardboard disc on the first liquid, then pouring the second carefully on this. When thus arranged, we may witness the interesting experiment of one metal being dissolved by the upper layer of liquid whilst the lower part of the same rod is receiving a deposit. The results of such an arrangement in some experiments performed by Mr. Gore, are shown in tabular form on the opposite page.

If we employ a glass trough divided into two equal compartments by a partition of porous earthenware cemented to the sides of the glass vessel, the range of experiments may be extended to such metals as gold and platinum, on which a deposit of the baser metals may be obtained when one end of a bent rod of gold or of platinum is made to dip into a solvent solution on one side and a strong solution of the base metal on the other side of the partition. Cyanide of potassium is a solvent for gold, and *aqua regia* a solvent for platinum. The process of electro-deposition known as the single-cell process, is, however, carried on generally by means of a compound cell consisting of a large containing outer cell holding the solution of the metal to be deposited, and an inner cell of porous earthenware holding the solvent solution and the metal to be dissolved

to furnish the electric current. In this arrangement the two liquids touch each other through the pores of the cell, but do not mix, and the two metals are connected by a wire above the liquid, and thus complete the circuit.

The cells of the battery known as the Daniell battery, invented by Professor Daniell, are thus constructed. In the original arrangement the outer cell was constructed of copper, but in the modern modifications of his invention, the outer cell may be of stoneware, porcelain, or glass, and the negative element (copper) contained therein be of any form, either a cylinder surrounding the porous pot, a plate, or a rod, as may suit the convenience of the maker. It is best, however, to have a large negative surface, and therefore a cylinder of copper makes the best negative element. This must be immersed in a saturated solution of copper sulphate, and provision must be made to keep the solution in a saturated condition by suspending therein a bag containing crystals of the copper salt, which dissolve gradually and so maintain the density of the solution. The positive element (zinc) is contained in a cell of porous earthenware immersed in the copper solution. This cell is charged with dilute sulphuric acid, which enters into combination with the zinc, forming zinc sulphate, and furnishing, when the two elements are connected, a current of electricity, having a potential of a trifle over one volt. As this force is quite enough to decompose a solution of copper sulphate, it not only deposits copper on the negative

element of the battery, but also furnishes enough current to decompose a solution of this salt in a separate vessel. As this force will also decompose gold and silver solutions, and is constant for long periods, the Daniell battery is esteemed one of the best generators of electricity for the purposes of electro-deposition.

§ 59. **Electrotype Experiments.** If we remove the copper plate or cylinder of a Daniell cell, and substitute a copper coil, brass medal, or other metal article connected to the zinc, it will (provided it is electro-negative to zinc) be coated with a deposit of copper. If the coin is soiled with grease, oil, or other animal substance before being placed in the solution, the deposit of copper will not adhere firmly to the coin, but may be peeled off when it has attained the thickness of paper. The inside portion of this envelope will then be found to have taken an exact impression in reverse of the features of the coin which it covered. The discovery of this fact by Mr. Spencer in 1836 led to the invention of the electrotype process of duplicating designs in copper. By this process any artistic design cut, or engraved, or stamped, or cast on any metal, or other substance, may be exactly reproduced in the most minute detail in copper. It has received the name of electrotype, because a forme of printing type may be exactly copied, and the copy used instead of the original for printing the book. Although the process may be put to such uses, it is rarely if ever thus employed at the present day, as it is more costly than the equally

effective stereotype process of duplicating formes of printing type. The chief employment has been in the duplication of engravings, for which it is eminently suitable. The engraved wood block, or other design to be copied, is first reproduced in wax or iu gutta-percha, or a similar plastic material which will take the fine lines of the engraving, and this copy is then carefully coated with blacklead to render its surface capable of conducting the electric current and receiving a coat of copper. Copper is then electro-deposited on this mould until the film of metal is deemed to be thick enough, when it is removed and backed with type metal, and mounted on a type-high wooden block for the printing-press.

As some experiments illustrative of this process will be found of some interest, I give a few directions for their performance.

1. *Electrotype of a Medal or Coin.* Valuable coins, however old, may be exactly duplicated in copper by the electrotype process. For coiu cabinets, where it is desirable to keep the valuable coins under glass to preserve them from the fingers of connoisseurs, and yet show them both ou the obverse and reverse side, this method of duplication has several advantages. Copies of both sides can be taken and backed to the required thickness, then cemented by their backs to the case under the glass, and thus be shown to friends side by side with the real coin. If the coins are of silver or of gold, the appearance of the original may be reproduced by gilding or silvering, directions for doing this being

given further on. The mould for duplicating coins, may be made of wax, of gutta-percha, of plaster of Paris, or of fusible metal.

a. To make a mould of gutta-percha, heat some of this material in scalding hot water until soft, roll it into a ball, press the ball on the centre of the coin, and work it with the finger and thumb until it forms a cake all over the coin and down over the edges, then put the coin on a bench, and a piece of metal heavily weighted on the gutta-percha at the back. Allow this to get quite cold and hard before removing the weights. *b.* To take a mould in wax, get some good beeswax and soften it by heat (and by working in the warm hand) until it is soft enough to be worked over the coin, as with the ball of gutta-percha, then set aside to cool and harden. It is advisable to lightly oil the coin before pressing on the gutta-percha or wax, to prevent these substances from sticking to the coins. *c.* To take a mould in plaster of Paris, get a cardboard tray large enough to hold the coin, and some good plaster of Paris. Oil the coin and place it in the box. Mix some plaster of Paris with water to the consistency of cream, and pour it in the box on the coin, stirring all the time with a feather to break up air-bubbles, then set aside to harden. When quite hard, remove the coin and gently dry the mould for several hours. When the mould is dry, bake it in an oven, and dip it whilst hot in linseed oil, then set aside for the oil to oxidize and harden. The mould should be treated two or three times like this, so as to get the oil well into the plaster,

and thus prevent it from absorbing water. *d.* Fusible alloy, fusible metal, or "clichee" as it is sometimes named, is an alloy of tin, lead, and bismuth in the following proportions :—

	Tin.		Lead.		Bismuth.
1.	1 part.	...	1 part.	...	2 parts.
2.	3 parts.	...	2 parts.	...	5 ,,
3.	1 part.	...	2 ,,	...	3 ,,
4.	3 parts.	...	5 ,,	...	8 ,,

Any of these will melt at the temperature of boiling water. Place the coin in a shallow metal tray, just large enough for the mould, and make both warm by placing them on a hot iron. Melt the alloy in a ladle or an old iron spoon, and pour it in the tray on the coin, then set aside to cool and harden. *e.* Other plastic substances and other methods may be employed, in fact anything that will take a clear impression of the coin, including stearine, paraffin wax, marine glue, sulphur, sealing-wax, shoemakers' wax, and gelatine. Wax may be melted and run into a tray on the coin, or made as directed for fusible metal. A mixture of white-lead and beeswax (one ounce of white-lead to one pound of wax) is superior to wax alone. Of all these substances, gutta-percha is the best for tho purpose, and plaster of Paris the most troublesome. An electro of a coin may be taken direct by coating the face with a very thin film of oil or of blacklead, and bedding one-half depth of the back in a cake of wax, having first laid a copper wire on the wax to be pressed in with the coin to form a metallic connection. A shell of copper is deposited

on the face of the coin, which is then removed and the obverse side similarly treated. As the oil on the coin will prevent adherence of the copper shell, this may be removed from the coin, and will be found to be a copy of the coin.

Moulds of wax, gutta-percha, plaster of Paris, and similar non-conducting materials must be made conduc-

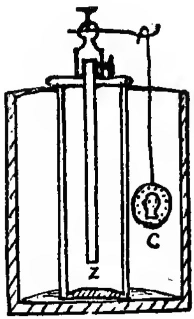


Fig. 136. Single-Cell Apparatus for Electrotype.

tive by coating them with best blacklead. First embed in the face of the mould, near the rim of the impression, the end of a thin copper wire, to hold up the mould in the solution, and to form a connection between it and the zinc in the porous cell. Then, with a soft brush, such as a sable or camel-hair brush, and finely powdered blacklead, brush the face of the mould until it has been fully coated and well polished with blacklead, some of which must also be brushed around the end of the copper wire to connect it with the blackleaded surface

of the mould. The mould should then be weighted with a scrap of lead to sink it in the copper solution, and suspended in the outer cell connected to the zinc of the inner cell of a Daniell battery, as shown at Fig. 136.

After several hours, the shell of copper will be thick enough to be separated from the mould. This must be carefully done if the mould is to be used again, the edges of the shell being raised all around with a thin knife before separating it from the mould. The back of the shell must then be cleaned from bits of wax, etc., and brushed with soldering fluid, then coated with solder to give the shell a necessary stiffness, and the ragged edges sheared off with a pair of stout sharp scissors. This done, some molten solder may be poured in the shell to fill it up to the thickness of the original coin, or it may be filled up with type-metal to the necessary thickness. This backing should be next levelled with a coarse file, and a thin disc of copper, furnished with a loop, soldered to the back.

Any medal, seal, engraved or stamped surface of metal or other material, may be copied in a similar manner if the design is not undercut, and is free from projecting or overhanging parts.

2. *Electrotypes of Fishes, Ferns, and Leaves.* Small fish such as minnows, whitebait, and sprats, may be copied in copper by a similar process, and then silver-plated to form brooches, ornaments for the hair, and other ornamental purposes. To take a mould of a fish, half fill a shallow cardboard box with fine sand, and bed one-half

o one side of the fish in the sand, leaving the upper half clean and clear. Next get some good plaster of Paris, and some clean water in a basin, stir the plaster into the water in small quantities until a mixture is made of the consistency of thin cream, then pour this at once into the box on the fish, whilst stirring with a feather to break air-bubbles. When this cake of plaster is dry, carefully turn it, with the fish and the sand, out of the box, trim the plaster carefully with a sharp knife around the fish, then replace the whole in the box, with the fish uppermost. Next get a piece of tissue paper and cut a hole in the centre to the shape of the fish and lay this in the box, surrounding the fish, and shielding the plaster cast from contact with the wet plaster about to be poured on it in the box. A plaster mixture is next prepared as at first, and poured on the fish until the box is filled. When this has set hard, the whole may be turned out of the box and the two moulds easily parted, as the tissue paper will have prevented adherence of the plaster to the plaster cast. The fish may now be taken out and the moulds dried and prepared as directed at *c* in the previous sub-section. The conducting wires from these moulds should pass around the edges, and the blacklead be spread to meet the wire on all sides. On suspending the moulds in the solution, care must be taken to brush off with a feather all the bubbles which form on the surfaces. The two halves of the copper fish must be backed with solder, then trimmed and soldered together.

Ferns and leaves are best copied by taking moulds of

them in wax. This is done by brushing the leaf or fern with hot beeswax, allowing the layer to cool, then adding another layer, and so on until a sufficiently thick cake of wax has been laid on the leaf to form a mould. The leaf is then carefully removed from the cold wax and the impression coated with blacklead in the usual

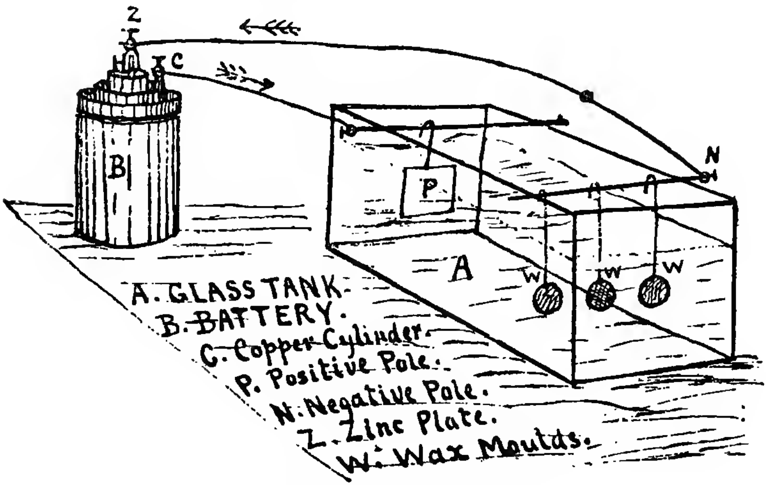


Fig. 137. Electrotyping Apparatus.

manner to render it conductive. Copies may be taken in plaster of Paris, the leaf or fern being backed by sand in a box, and plaster poured on the leaf as for copying coins; but this process does not so well preserve the natural features of the leaf.

3. *Electrotypes of Stamped or Engraved Surfaces.*

These are produced in the same way as those of coins and medals, the moulding material generally used, being best yellow beeswax. The engraved wood block, stamped metal design, or forme of printing type, is placed in a suitable frame with raised sides to prevent the wax from flowing off from the surface, and melted wax is poured into the frame until a cake of the requisite thickness has been obtained on the surface to be copied. When this is quite cold, it is separated from the original, furnished with conducting wires, and coated with blacklead, then immersed in a suitable depositing solution, connected to a separate source of electric power such as a battery or a dynamo. This class of work cannot be well done by the single-cell process, and therefore rightly belongs to the class mentioned in the next section. When a shell of the requisite thickness has been obtained, it is backed with solder and with type-metal to form a rigid plate, which is then secured by brads to a "type-high" slab of beech, mahogany, or oak.

§ 60. **Electro-Deposition of Metals.** If while conducting the single-cell processes mentioned in the previous section, we connect the zinc in the porous cell with one stud of a galvanometer, and the mould in the copper solution with the other stud of the instrument, the needle will be at once deflected, and thus show that an electric current is passing from the copper to the zinc outside the solution. The single-cell arrangement is therefore a cell of an electric battery, and will furnish power outside itself. This may be proved by

taking two, three, or more of such cells and connect them in series—that is, connect the mould in one containing cell to the zinc in the porous pot of the next cell, and the mould of this to the zinc of the next, and so on throughout the series, leaving a zinc unconnected at one end of the row and a mould unconnected at the opposite end. Now take a saturated solution of copper in a separate vessel, and add to it one part of sulphuric acid to each twenty parts of solution, then immerse a copper plate at one end, connected to the mould left free in the series above-mentioned, and another mould at the opposite side connected to the free zinc of the series. An electric current will then pass through all the series of vessels, and also through the separate vessel last added, dissolving the copper plate on one side and depositing copper from the solution on the other. It is not necessary to have several such cells in series, in fact one alone is quite enough to effect the decomposition of the copper solution in the separate vessel. Other solutions may be decomposed by current from such an arrangement; for instance, silver may be deposited from a silver-plating solution, or gold from a gilding solution, whilst single-cell electrotype operations are proceeding in other vessels and furnishing the necessary current; but it is usual to have a separate battery of Smee or Daniell cells for such a purpose, or to use current supplied by a suitable dynamo-electric machine. Metal may be set free by electrolysis from several solutions of metals, and under suitable conditions may be deposited on metal plates forming the

cathode system of the depositing arrangement. Some metallic solutions will, however, not yield their metal at the cathode, because the highly oxidizing character of the liberated ion at the anode at once converts the metal into an oxide. Others, such as the nitrates, chlorates, bromates, iodates, selenates, and phosphates, will either not yield a metallic deposit at all, or in such a condition as to be of no use. Some solutions are easily decomposed by light and by atmospheric influences, and are therefore not available for electro-depositing experiments. Among the most useful are those of the cyanides, sulphates, and chlorides of metals. The fluorides and bromides have also been employed.

A good depositing solution should yield its metal only to a current of electricity, and should at the same time set free a solvent capable of dissolving the anode. A list of suitable solutions, and directions for working them, are given in the "Electro-plater's Handbook." As a guide to experimental operations, I give here a few directions for making gilding and silvering solutions.

1. *Silver-Plating Solution.* To make one pint of silver-plating solution, procure 6 dwts. of silver nitrate and dissolve in ½-pint of distilled water in a glass vessel. Next dissolve 4 dwts. best cyanide of potassium in another ½-pint of distilled water. Add some of the cyanide solution to the silver nitrate solution in very small quantities at a time, with frequent stirring, until the last few drops ceases to form a white cloud, but appears to clear the cloudiness already formed. There

should now be at the bottom of the glass vessel a quantity of white curds, which is cyanide of silver. Allow this to settle down, then carefully pour off the liquid and pour a quantity of fresh water on the precipitate, pour off this and repeat the operation two or three times to thoroughly wash the silver cyanide. Then pour in the remainder of the potassium cyanide solution, which will dissolve the cyanide of silver and form the double cyanide of silver-plating solution. Dilute this with distilled water to make one pint of solution, and work it with an anode of pure silver, and one or two cells of a Daniell or Smee battery.

Coins and medals to be silver-plated, must be freed from all dirt and corrosion by boiling them in strong soda water, then brushed with pumice and water or with finely powdered bath brick, and finally rinsed in water before being placed in the plating solution.

2. *Gilding Solution.* Dissolve 4 dwts. of good cyanide of potassium in 1 pint of distilled water contained in an enamelled iron saucepan. Make this solution scalding hot, but not boiling, and suspend in it two strips of pure gold, one of which is connected to the zinc, or positive element, and the other to the copper, or negative element of a battery of three cells in series. Pass a current from one piece of gold to the other for a period of three hours, at the end of which time some of the gold will have dissolved from the plate connected to the negative element and have entered into combination with some of the cyanide in solution to form the double cyanide of gold and potassium gilding

solution. The two strips may then be suspended from the negative element to form the anode, and the solution may be worked by one cell of a Daniell or Smee battery, gold being freely deposited from it, when made hot, on silver and copper coins. The same care must be taken in cleaning articles to be gilded, as for silver plating.

3. *Nickel Solution.* To make a nickel-depositing solution, dissolve 2 ounces of the double sulphate of nickel and ammonium salt in 1 pint of hot water, then strain it through a filter, and add, when cold, about a teaspoonful of liquor ammonia. This solution should be contained in a stone-ware, porcelain, or glass vessel, and worked cold with at least 4 cells in series of the Daniell or Smee batteries. Even more care must be taken in cleaning articles for nickel-plating than for silver-plating.

Amateurs and experimenters who may wish to carry on these experiments without having the trouble of making solutions and setting up a battery, may get a portable set of apparatus for the purpose, from Messrs. J. E. Hartley & Co., St. Paul's Square, Birmingham, or from the Electric Stores Co., Cannon Street, London.

Students of the science will find further information in Gore's "Electro-Metallurgy," Napier's "Electro-Metallurgy," Watt's "Electro-Deposition," and in the "Electro-plater's Handbook." [1]

[1] "Electro-plater's Handbook," price 3*s.*; Whittaker & Co., London.

CHAPTER VI.

MISCELLANEOUS ELECTRICAL EXPERIMENTS.

§ 61. **Thermo-Electrical Experiments.** If bars of two such metals as bismuth and zinc are soldered together at one end, and the two free ends are connected to the binding screws of a delicate galvanometer, the needle of this instrument will be deflected when the junction of the two metals is warmed by the flame of a spirit lamp. This property of metals was discovered by Professor Seebeck of Berlin in 1821, and has since received close attention from such able men as Matthiessen, Kohlrausch, Becquerel, Neumann, Wheatstone, Svanberg, Nobili, Clamond, Melloni, Poullet, and Peltier. The phenomena of thermo-electricity has therefore been fully investigated, and the results reduced to an exact science. The researches of Dr. Matthiessen led him to classify a number of metals in regular order on a graduated scale of electric value in their relations to each other under certain conditions of temperature. The published results of his investigations are therefore of great value to students. Dr. Matthiessen's list is as follows :—

Bismuth	+	25·0	Gas Coke	—	0·1
Cobalt	+	9·0	Zinc	—	0·2
Potassium	+	5·5	Cadmium	—	0·3
Nickel	+	5·0	Strontium	—	2·0
Sodium	+	3·0	Arsenic	—	3·8
Lead	+	1·03	Iron	—	5·2
Tin	+	1·0	Red Phosphorus	—	9·6
Copper	+	1·0	Antimony	—	9·8
Platinum	+	0·7	Tellurium	—	179·9
Silver	+	1·0	Selenium	—	290·0

The above list of figures is not constructed on any basis of relation to a standard of electrical measurement, such as a volt, but only in relation to its several parts.

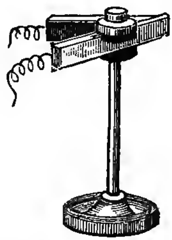


Fig. 138. Thermo-Electric Pair.

For instance, taking tin, copper, and silver as being equal to each other, and therefore not capable of producing a current when soldered together and heated at the point of junction, and comparing them with lead and bismuth, we shall find a couple of the latter metal and silver giving a current 25 per cent. stronger than a couple of lead and silver, and the current will pass from the bismuth to silver. On the other hand, silver

is positive to gas coke, but only to the extent of 0·1 per cent., whilst selenium is negative to silver to the extent of 290 per cent. The strongest thermo-electric pair would therefore be one of bismuth and selenium, but here practical difficulties present themselves, as selenium has a high resistance, and cannot be soldered to bismuth, and is also a rare and costly element. A pair of antimony and bismuth bars fixed as shown at Fig. 138, are therefore generally used in thermo-electric experiments.

Fig. 139. Thermo-Electric Pair and Indicator.

Fig. 139 shows a similar pair arranged with a compass needle between, as an indicator. The value of Matthiessen's figures in relation to a known electrical standard, may be shown by the following results of experiments. With a bismuth-copper couple and a difference of temperature between the ends valued at 100° Centigrade, or that between the boiling point and freezing point of water, Wheatstone obtained a current equal in E.M.F. to $\frac{1}{95}$th that of a Daniell cell, and Neumann found the

value to be only $\frac{1}{256}$th of a volt. Kohlrausch found the E.M.F. of an iron-silver couple with a difference in temperature of 15°, to be only $\frac{1}{6600}$ that of a Daniell cell. The E.M.F. of a thermo-electric battery may be increased by soldering several of the couples together to form a zigzag alternate arrangement of negative and of positive elements, and heating one series of junctions whilst the opposite series is kept as cold as possible. Even when thus arranged, and 70,000 pieces of copper and iron employed to form a thermo-pile, we should only get a difference of potential of 100 volts with a difference of 100° C. temperature between the ends. In the "Electrician Primer," No. 20, it is stated that "The most powerful thermo-piles which have been contracted, have not exceeded an electrical power of 12 watts each, a power sufficient only for a glow lamp of 3 candle-power. These are massive, bulky contrivances heated by coal gas." The result of experiments with thermo-piles as generators of electricity, goes to show that they require three times more coal gas to work them than would be required to work a gas engine driving a dynamo giving an equal quantity of electric energy.

§ 62. **Electric-Light Experiments.** If we make up a battery of 4 quart-size Bunsen cells in series, and connect two fragments of carbon by stout copper wires to the poles of this battery, then bring the ragged edges of the carbon fragments together, we shall observe dazzlingly brilliant white points of light traversing the carbon edges. These sparks are the electric light on a

small scale. By increasing the number of cells until some 14 to 16 are connected in series, we shall find the size and length of the points of light increase with each cell added, until the copper connecting wires get too hot to hold in the naked hand, then the fragments of carbon will get white hot at the edges, and, as the number of cells increase, the light will also increase to a white flame playing between the edges or points of the carbon. Gas-retort carbon, or the carbon employed for battery plates, may be employed for this purpose. If small rods or pencils of carbon are substituted, and placed in suitable holders, the experiment may be more conveniently performed, and the gradual growth of the electric arc lamp may be observed.

It will be noticed first that the light is caused by particles of carbon getting white hot and burning away whilst the carbons are in contact, but the light ceases where these particles are consumed. As the power of the battery increases, the light will bridge over a slight space between the carbons and be maintained after the carbons are separated. This space will increase with an increase of cells, and finally assume the form of a bridge of light. It will also be noticed that the light fades and ceases when the space is increased too much. If the space between the carbons can be always maintained at the same, the light is steady, but one carbon burns away more rapidly than the other, and this renders the regulation of space difficult. To have an arc lamp, therefore, we must provide an arrangement for bringing the carbons together at the same rate as they

are being consumed. Fig. 140 shows how this may be effected by hand, and this form of arc lamp regulator is one of the most effective for arc light experiments. The parts are very simple, and may easily be made at home, the main features being the carbon-holders of metal, *a* and *b*, and the rack-work arrangement, *c*, for

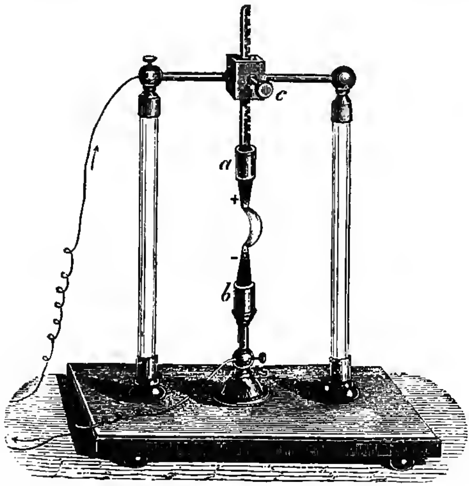


Fig. 140. Arc Light Regulator.

raising or lowering the carbon-holder, *a*. It is not necessary to have the pillars of glass. These supports may be of metal or of wood. Fig. 141 shows another form of hand-regulating arc lamp, the upper carbon-holder either sliding stiffly in the socket of the brass supporting arm, or working therein by means of a screw. As, however, an arc lamp must be self-regulating to be of

any practical use, I give an illustration of a simple form of arc lamp regulator.

When the carbons are not wholly separated to form an arc of light, as shown at Fig. 140, the lamp is named a semi-incandescent lamp, because the light given is partly that of incandescing particles of carbon and partly short arcs of light playing between the crum-

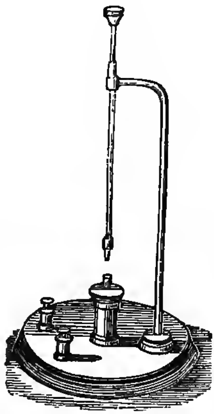


Fig. 141. Arc Light Regulator.

bling particles of burning carbon. Fig. 142 shows a simple form of self-regulating arc lamp, sold by Messrs. King, Mendham & Co. Fig. 143 shows a small model semi-incandescent lamp, sold by Mr. G. Bowron, Praed Street, London. These small lamps will give a light with current from 6 Bunsen cells. The small electric lamps contained in egg-shaped glass globes seen in shops and some private houses, and shown at Fig. 144,

are named incandescent electric lamps. A thin thread of carbon is inserted in a glass globe and attached to

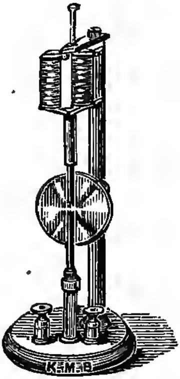


Fig. 142. Small Arc Lamp.

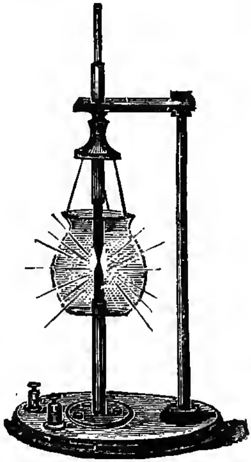


Fig. 143. Bowron's Semi-Incandescent Electric Lamp.

platinum wires fused into the neck of the globe. The globe is then exhausted of air and hermetically sealed

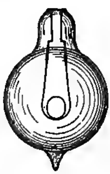


Fig. 144. Incandescent Electric Lamp.

by fusing the tube through which the air was drawn. When a suitable quantity of electricity at a sufficiently

high tension, is sent through the carbon thread, it is raised to a state of incandescence, that is, at a glowing white heat, and the glow from this constitutes the light. The carbon thread does not burn away, because there is no oxygen in the globe to combine with the white-hot carbon; but if the strength of the current is increased beyond that necessary to properly light the lamp, the carbon thread will break under the extra strain, and the light be at once extinguished. These lamps cannot be made by the amateur, as they can only be produced by the use of special machinery and the employment of skilled labour.

Imitation incandescent lamps may be made by the amateur with a platinum wire (instead of a carbon thread), enclosed in a glass globe which need not be exhausted of air. The wire may be raised to a white heat by sending a strong current through it, and thus a glow lamp may be improvised. The wire is, however, liable to rupture from a slight increase of current, and, as it expands as it gets hot, the white-hot loop is liable to drop and then fuse. One peculiarity may be noted in comparing the relative properties of a platinum and a carbon wire. As carbon gets hot under the influence of an electric current, it offers less resistance to the current; but platinum, on the contrary, offers a higher resistance when hot than when cold.

Readers who may wish to extend their knowledge by experiments with electric lights, are recommended to get "A Guide to Electric Lighting," by S. R. Bottone, price 1*s.*; [1] Allsopp's "Practical Electric Light Fitting,"

[1] Published by Whittaker & Co., 2, White Hart Street, London.

5*s.*; and "Arc and Glow Lamps," by Julius Maier, 7*s.* 6*d.*

§ 63. **Electric Amalgams.** *Cavallo's Electric Amalgam* is composed of broken tinfoil 1 part, mercury 2 parts, powdered chalk $\frac{1}{4}$ part, all well rubbed together in a mortar until the mixture forms a paste. *Zinc amalgam* is composed of Cavallo's amalgam $\frac{1}{4}$ part, zinc 1 part, mercury 4 parts, powdered whiting $\frac{1}{10}$ part. Melt the zinc, and heat the mercury to 220° Fah. Pour the hot mercury into a covered wooden box, then pour in the melted zinc, put on the cover and shake the whole well together. When this mixture is cold, triturate it in a mortar with the whiting, Cavallo's amalgam, and enough tallow to make it into a paste. There are several other methods of making electric amalgam, but this has been considered the best. It is employed in experiments with electrical machines, to smear the silk flaps and rubbers.

Electric Cement. Melt equal parts of beeswax and rosin together, and stir in one-fourth of their weight of red ochre, until all has been well mixed. This cement is used for fastening the metal portions of electrical instruments to their insulating supports.

Electric Varnish. Powder some common sealing-wax in a mortar, or otherwise break it into small pieces, then place the fragments in a bottle with spirits of wine, and keep in a warm place until all the sealing-wax has been dissolved. Shake occasionally. This varnish is used to cover magnets, and the exposed metal parts of electrical apparatus.

§ 64. **Guides to Electrical Experiments.** Although some hundreds of electrical experiments have been enumerated in the foregoing pages, the author has not been able to compress into such a small compass more than a tithe of those known to him. Others, not included in this book, may be found in the following works:—

"The Play-Book of Science," price 7*s.* 6*d.*; Routledge & Co. "Electricity in the Service of Man," 9*s.*; Cassell & Co. Ganot's "Physics,"; Longmans, Green & Co. "Elementary Lessons in Electricity and Magnetism," by S. P. Thompson, price 4*s.* 6*d.*; and in several other text-books on Electricity and Magnetism, all of which illustrate their lessons by means of experiments. To students who may wish to pass from the playground of scientific amusement into the wider field of experiments for practical purposes, I would recommend a perusal of the "Electrician Primers," vols. i. and ii., both of which will give a general insight into the practical application of electricity to various industries. Those who may wish to see what has been done in the way of electrolytic experiments, may study with advantage the little book on "Electro-Metallurgy," by G. Gore, price 6*s.*; published by Longmans, Green & Co.

Several other applications of electricity and magnetism to industrial purposes have been described in the books published on technological and scientific subjects by Whittaker & Co., a full list of these being given in the advertisement sheets at the end of this book.

Messrs. Dollond & Co., 35, Ludgate Hill, London,

issue with their two-guinea set of electrical apparatus, a sheet of printed instructions for performing thirty experiments, some of which are not included in the list given in preceding chapters of this volume.

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Butler & Tanner, The Selwood Printing Works, Frome, and London.